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TARGET ACQUISITION STUDIES: VISUAL ANGLE REQUIREMENTS FOR DIRECTLY VIEWED TARGETS

James W. Bergert, et al

Martin Marietta Corporation
Orlando, Florida

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James W. Bergert
Frank D. Fowler

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ABSTRACT

This study investigated the basic target acquisition capability of the unaided eye in a simulated real-world environment. Pilot performances on target detection and recognition tasks were examined under two test paradigms:

1. Search task for unbriefed targets and target areas;

2. Psychophysical threshold visual angle requirements for briefed targets.

It was found that, as in previous studies using TV augmented viewing systems, there was a large decrement in performance at low contrast levels of 5% to 15% for both target detection and recognition. Differences in performance between search and threshold tests decreased to a constant value above approximately the 20% contrast level. At low target to background contrast levels, the general contrast level of background objects was higher than that of the target allowing maximum time for evaluation of all area objects. As a result, all high contrast non-targets were eliminated prior to reaching the visual threshold for the low contrast target which was then detected. Consequently, there were no significant differences between search and threshold tasks at low contrast levels. Comparison of the static and dynamic threshold tests revealed no differences in the observer's performance with limited or unlimited time for target examination.

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SYNOPSIS

This study investigated the basic target acquisition capability of the unaided eye in a simulated real-world environment for air-to-surface search missions. The data were collected using the three-dimensional 600:1 scale terrain model in the Guidance Development Center of the Orlando Division of Martin Marietta Corporation. Simulated flights at 3000 feet altitude and 350 knots airspeed were flown against targets having target-to-background contrasts of between 5 and 50 percent. Three paradigms were employed to examine several experimental parameters involved in target detection and recognition:

1 A dynamic search task over a pre-briefed 1/2 mile by 1/2 mile target area with an unbriefed target position;

2 Static and dynamic tasks to establish the psychophysical threshold for recognition of a target at a briefed target position;

3 Static and dynamic tasks to establish the psychophysical threshold for recognition of a target at a briefed target position.

Former military pilots, experienced in air-to-surface target acquisition missions, served as subjects.

The objectives of this study were to:

1 Determine the relationship of target-to-background contrast levels on pilot performance in detecting and recognizing targets during tasks requiring search of a pre-briefed general target area,

2 Determine the relationship of target-to-background contrast levels for detecting and recognizing targets when the search task was eliminated to obtain psychophysical baseline data on visual angle and range requirements.

The targets were silhouettes of three simple buildings with areas, perimeters and other dimensions approximately equivalent to each other. Two dimensional targets were used in order to maintain a consistent brightness across their surface. The contrast values of these targets against their backgrounds were 5, 10, 15, 20, 25, 35, and 50 percent.

These values were measured to be within ± 2 percent throughout, thereby maintaining precise contrast control.

The principal results and conclusions are summarized below:

1. Performance Dependent on Contrast

On all tests the subject's target acquisition capability improved with an increase in contrast up to 20 - 25 percent, where his performance leveled off. The largest effect was at the low contrast levels of 5 to 15 percent where visual angle requirements for detection ranged from 1.5 arcminutes on the threshold task up to 3.8 arcminutes for the search task.

At the closer ranges required for recognition, visual angles for the search task ranged from 2.5 arcminutes at 25 percent contrast, to 4.8 arcminutes at the 5 percent level. Threshold values were similar to search values at the 5 percent level (4.6 arcminutes) and decreased exponentially to 1.2 arcminutes at the 35 percent contrast level.

2. Search Performance

Differences in operator performance between the search task and the pre-briefed target detection tasks showed significant differences at all levels of contrast indicating the increased time and visual angle requirements needed to search an area and then detect the target. For the recognition tasks, however, low contrast of the target appeared to mask the effects of search so that no difference existed between these tasks for the search or pre-briefed conditions. Only at contrast levels of 25 percent and above was the search task found to be more difficult than the threshold or pre-briefed task.

3. Time Dependent Response - Static vs. Dynamic Conditions

Unlimited response time had no effect on whether a subject could detect or recognize a target throughout the total contrast range. A constant difference existed between the dynamic and static detection tests as well as the dynamic and static recognition tests, however, these were not statistically significant. These differences appeared to be due to subject reaction time.

INTRODUCTION

A. BACKGROUND

This study was performed as one step in the development of a set of basic data on target acquisition. The first experiment (Reference 11) examined target acquisition using a television system equipped with various fields of view (FOV). A high degree of target-to-background contrast control was used in order to determine an accurate relationship between target contrast, TV FOV, and target acquisition performance. This study investigated the target acquisition capability of the unaided eye in a simulated real world environment. Experiments were constructed so that data would be obtained on basic target acquisition tasks involving search over a pre-briefed 1/2 X 1/2 mile area (simulated). Tasks were also designed to determine target detection and recognition thresholds by eliminating both the search function and time-dependent responses.

Field measurements, reconnaissance photo interpretation and other simulation studies (References 2, 3, 6, 7, 13) have indicated that target-to-background contrast was the most critical factor in acquiring and recognizing targets. An examination of these reports has also shown that while this contrast variable is the most critical, it has also been the one most difficult to control - both in field studies and simulation.

The series of experiments being conducted at MMC both on this contract and others (References 11 and 12) has provided the highest degree of contrast control to date. Because of the important nature of this contrast variable, all other extraneous factors, e.g., target shape and detail, varied backgrounds, and relative motion have been minimized in order to eliminate as many interactions as possible.

B. OBJECTIVES AND APPROACH

Basically, this study investigated the component parts of a target acquisition problem separately, and under their dynamic interactions. This included target search, detection and recognition in an unbriefed target mode and in static and dynamic threshold modes. The separate objectives were:

1 To determine the effect of target-to-background contrast on the visual angle and slant range requirements for target detection and recognition;

2 To determine the effect of target-to-background contrast on the visual angle requirements for target detection at the minimum visual angle, i.e., detection threshold, in both the static and dynamic modes;

3 To determine the effect of target-to-background contrast on the visual angle requirements for target recognition at the minimum visual angle, i.e., recognition threshold, in both the static and dynamic modes.

From an operational standpoint, the roles of detection and recognition cannot be separated for either briefed or unbriefed target positions. In either case, detection has to occur prior to or simultaneously with recognition. Once the pilot has navigated to the general area of the target, his target acquisition task consists of several subtasks. He must locate the target area, search the area for the target in question, evaluate potential targets until the actual target is detected and, if required, identify the target. If the exact target position is known, the locating and searching tasks are eliminated and the pilot will more readily detect and recognize the target at a greater range. An object at the prebriefed position may require less definition of shape to be recognized or may be evaluated successfully at a longer range from features which might also be characteristic of other non-target objects in the general target area.

The target detection requirement will be affected by several criteria within the available briefing information. Some of these criteria are outlined below:

1 The limitation of the target by object class, e.g., vehicles, buildings, aircraft, etc;

2 The limitation of the target within an object class, e.g., tanks, trucks, armored personnel carriers;

3 The availability of cues for target area location;

4 The amount of "noise," i.e., objects other than targets, in the target area which have size and shape characteristics similar to the target;

5 Knowledge as to the probable target-to-background contrast ratio;

6 Knowledge of the location of the target in proximity to recognizable terrain features.

The target detection task is, in reality, a process of elimination (provided that detection occurs prior to the target recognition threshold).

Target detection occurs when enough of the briefing information has been correlated with the area under consideration to allow selection of an object as a target. As stated by Bliss (Reference 3), "Detection is the determination that some object is present at a location compatible with its being the target; ..." It is an easier task to distinguish the features of a target when the object under consideration is known to be the target than when several objects are potential singular targets. For example, a pilot would readily detect a single vehicle target from long range, in an open area, by "seeing" its characteristics, if his briefing had included a target in that position. This same target might not be so obvious, at that range, if it were near similar appearing objects such as boulders, canvas covered buildings or supplies. The need to detect a target, from the available choices, would require closing the range until the non-targets could be recognized and eliminated or until the target itself could be discriminated from its surroundings.

Because of the difficulty in trying to show a simple relationship between target detection and any of the controlling parameters, this study was limited to those factors described below.

Five tests were designed to determine an operator's target detection and recognition capability. The first of these tests presented the target in a 1/2 mile by 1/2 mile prebriefed, essentially open area or field with variations in the terrain mottling and vegetation accounting for background "noise." The subject was required to search the target area and detect and recognize the target during simulated flights toward the target area.

The remaining four tests were designed to study the basic target detection and recognition thresholds of the human eye, in both dynamic and static modes. For detection, these tests reduced the background noise which required evaluation, by limiting the search requirement to an area, on the terrain model, approximately equal to that covered by the subject's foveal vision. For recognition threshold determination, target detection was achieved by designating the target on the terrain model. This provided a single object for evaluation and eliminated the possible effects of background noise.

I. TECHNICAL DESCRIPTION

This section discusses the experimental design and the variables and technical factors that were involved in this study.

A. EXPERIMENTAL DESIGN

Each of the five individual tests was composed of the same basic variables in subject briefing, target search requirements, and simulated airspeed, as required by the objectives of the tests.

<u>Test 1</u>: Target Acquisition with the Unaided Eye

The objective of this test was to determine the visual angles obtained at target detection and recognition for simple building targets and the relationship between these visual angles and the contrast of the target. Six target-to-background contrasts, three offset levels, three target shapes and five subjects were used. The offsets served as replications for each target treatment and provided a random search task within each target area. The target contrast values and shapes were systematically varied and presented to the subjects in counterbalanced order.

The following are the parameters for the first test:

Test Parameters	Number	Values
Target/Background Contrast	6	5, 10, 15, 20, 25 and 35 percent
Target Size	1	22.5' X 45' (simulated)
Target Shapes	3	Left Shed, Right Shed, House
Target Offset	3	Levels 1, 2, and 3
Flight Altitude	1	3000 ft (simulated)
Flight Airspeed	1	350 Kts (simulated)
Subjects	5	Former Military Pilots

<u>Test 2</u>: Determination of the Target Detection Threshold for the Unaided Eye, Dynamic Mode

This test was designed to determine the direct vision, target detection thresholds and the relationship between these thresholds and the target in a dynamic, range closure condition. Four target-to-background contrast ratios were systematically varied on three

replications and presented to the five subjects in a counterbalanced order. Three target shapes were used in this test and their application is discussed in Part E of this section.

The following are the parameters for Test 2:

Test Parameter	Number	Values
Target/Background Contrast	4	10, 25, 35 and 50 percent
Replications	3	Random Target Placement
Target Size	1	25' X 12.5' (simulated)
Target Shape	3	Left Shed, Right Shed, House
Flight Altitude	1	3000 ft (simulated)
Flight Airspeed	1	350 Kts (simulated)
Subjects	5	Former Military Pilots

Test 3: Determination of the Target Detection Threshold for the Unaided Eye, Static Mode

This test was designed to determine the target detection thresholds of the unaided eye and their relationship to the contrast of the target when the time allowed for target search and evaluation was unlimited. The same experimental design and parameters which were used in Test 2 were repeated for this test except that the airspeed was eliminated and static range closure steps were employed. The static steps were made in range changes which provided one-tenth of an arcminute variation in subtended visual angle.

Test 4: Determination of the Target Recognition Threshold for the Unaided Eye, Dynamic Mode

This test used the same parameters at Test 2 above to determine the target recognition thresholds and their relationships to target contrast. The parameters were again systematically varied and presented to the subjects in a counterbalanced order.

Test 5: Determination of the Target Recognition Threshold for the Unaided Eye, Static Mode

This test was designed to determine the target recognition thresholds of the unaided eye and their relationship to target contrast when detection had been assured and the time allowed for target evaluation was unlimited. The same experimental design and parameters which were used in Test 4 were repeated for this test except that the airspeed was eliminated and static range steps were employed. The static steps were made in the same manner as in Test 3.

B. VARIABLES

Most of the variables affecting target acquisition were held constant in order to provide baseline information on those which would fulfill the study objectives. Examination of the total relationship of the target with its background has to be evaluated in order to determine both those criteria affecting the total target acquisition task and the relationship of its individual components. For the target and background Gestalt, the major surround variable was the type and amount of "noise" in the background, i.e., contour, vegetation and objects, both manmade and natural combined with the target characteristics of size, shape, and contrast. If the remaining parameters are held constant, the amount of similarity between the background "noise" and the target characteristics will determine the difficulty of the target acquisition task.

A realistic flight problem was defined to provide a set of constant parameters about which the target and background relationship could be assessed. The flight parameter values selected were considered to be representative of those which might be employed by a jet attack aircraft while searching for small tactical targets.

The targets were randomly placed in a variety of backgrounds including open fields, desert areas, and basically open areas with an occasional tree or similar vegetation. All of the areas were realistically mottled in appearance which provided the limited variation in background required in this study.

The variables which were selected for investigation were target-to-background contrast and size of ground area to be searched. The following additional variables were held constant at values consistent with real world conditions and aircraft performance.

- Aircraft Velocity
- Aircraft Altitude
- Type of Target Background
- Flight Path/Target Position Relationship
- Total Scene Illumination
- Type of Target

The dependent variables which were recorded to evaluate the subjects' performance were visual angle, slant range and time. Since the surface of the 2-D targets lacked any detail which might have aided in detection or recognition, the visual angle upon which detection or recognition was dependent in these tests was a function of the overall target dimensions. The definition of visual angle used in this report was based on the largest vertical measurement of each target as projected into the plane normal to the subjects' line-of-sight. This dimension was used since it was the primary distinguishing characteristic of all three targets.

C. TARGET TO BACKGROUND CONTRAST

In this series of studies, the targets were darker than their respective backgrounds and the contrast relationship was defined by the equation

$$C = \frac{B_b - B_o}{B_b}$$

where:

B_o = brightness of the object

B_b = brightness of the background

This formula was used by Blackwell (Reference 1) for objects darker than their background; it yields contrast values from 0 to 1.0.

This study was conducted with colored targets placed against a background of identical hue but differing in brightness. The laboratory lighting was adjusted to provide a constant brightness for each target and background, as measured from the observer's position for all subject to target distances. Measured tolerance for contrast variation between the target and background was $\pm$ 2.0 percent, i.e., for the 25 percent level the contrast range could be 23 - 27 percent. (See Part G, Control of Variables.)

D. TARGET BACKGROUND

The target backgrounds were selected from areas on the terrain model in the Optical Guidance Laboratory (see Appendix A). These areas had relatively constant reflectance in the immediate vicinity of the target to provide approximately equal target-to-background contrast ratios on all sides of the target.

The criteria for selection of the target areas were that:

1 Only open fields/areas with a minimum of large vegetation and objects in the immediate vicinity of the target position would be chosen.

2 The areas would have a minimum brightness of 100 foot-lamberts under the test lighting conditions (as measured at the position of the observer's eye).

3 The terrain contour in the area of the target position would not obstruct the view of the target during range closure, and the target background would not change due to the angle from which the scene was viewed.

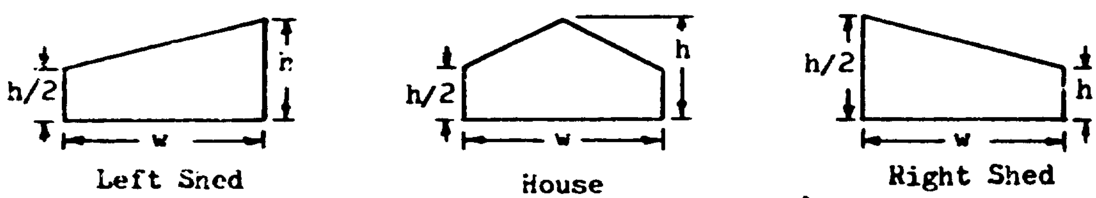
Based on these criteria, the target areas were selected by viewing the proposed areas through a telescope as range closure was effected. This allowed detailed evaluation of each area. The areas were then photometered from the eye position of the observer and final selections were made.

E. TARGETS

Two-dimensional targets were used in this study because unlike three-dimensional targets, surface brightness could be controlled. The targets were tilted away from the subject at an angle of 45 degrees to the horizontal plane which produced even illumination of the viewed surface and maintained a relatively constant vertical dimension as range closure was effected.

Three target shapes were selected for use in this study. Since this experiment did not attempt to study the effect of target shape on the target acquisition or recognition task, distinct targets with similar inherent characteristics were selected. From a review of the effect of target shape on target acquisition (References 4 and 8), it was concluded that for targets of the same maximum vertical and horizontal dimensions, their areas, perimeters, and perimeter-to-area ratios were the major controlling factors affecting acquisition. Using these criteria, three target shapes were selected that had equal areas, perimeters that varied a maximum of 2.9 percent, and perimeter-to-area ratio with a maximum variation of 2.8 percent. An exploratory study was conducted with six subjects to assess the relative effect of target shape. There was no significant variation in detection and recognition ranges (Reference 11).

The selected shapes and the dimensions used for the particular tests are given below, in Figure 1. A pilot study showed that, in order to obtain about the same probabilities of detection and recognition for all tests, larger targets were required for Test 1 (Target Acquisition with the Unaided Eye).



Test 1: w = .75" (37.5', 600:1 scale), h = .375" (18.75', 600:1 scale)

Test 2,3,4,5: w = .5" (25', 600:1 scale), h = .25" (12.5', 600:1 scale)

Figure 1. Two-Dimensional Target Shapes

F. SEARCH AREA

Test 1, in this study, was the direct vision corollary of the television unbriefed target acquisition test reported in Reference 11. The search area was the same size as that used in the previous study - 1/2 mile by 1/2 mile. The subjects were briefed on the area boundaries and each area contained a single target.

The 1/2 square mile area was selected as typical of the amount of area that must be searched by a pilot when the target position is briefed as "near the intersection of two roads" or "just north of the wooded area," etc. As described in subsection H of this section, vertical and oblique photographs of the entire terrain model were used for subject briefing. The target area was marked on the vertical view photograph and the subjects were permitted to study the photograph for as long as they desired.

For Tests 2 and 3, a search area was provided that would require evaluation of potential targets and yet eliminate the search requirement. This was a circle of 10" radius (actual, 500' scale) which, when observed from an elevation of 5' (actual, 3000 feet scale) at the 30' range appeared elongated horizontally. Harcum stated in Reference 9 that: "Concerning detection sensitivity for the various eccentric portions of the visual field the consensus of experimental results seems to be that the areas above and below fixation exhibit higher thresholds and those areas to the right and left of fixation yield lower thresholds. The iso-detection contours for stationary spots, then, are generally oval with the long axis corresponding to the horizontal meridian of the visual field."

In Tests 4 and 5, the problem started with target detection eliminated through precise target designation on the terrain model by the test conductor.

G. CONTROL OF VARIABLES

1. General

While this study involved the control of several variables, the parameter that was most difficult to regulate was target-to-background contrast. The stated objectives of this study required that specific contrasts be established and maintained for each treatment.

The control of contrast is a difficult task in any experiment of this type, and particularly when portions of the test are conducted under dynamic conditions, or when the placement of the stimulus material is varied. The procedures and techniques employed, the problems encountered, and the contrast values obtained for this experiment are described in this section.

The following variables influence the accuracy with which desired contrast values can be measured and controlled:

1 The accuracy and precision of the photometer,

2 Illumination control throughout the area of target placement;

3 The degree to which the target surface can be made to reflect the desired light level in relation to its background:

4 The changing target/background relationships in relation to the position of the observer's eye.

2. Photometer Accuracy

A Photo Research Corporation Spectra Pritchard photometer was used to determine the various target and background brightnesses for control procedures and contrast determination. Since this photometer was central to most of the calibration and control, a previous analysis (Reference 11) was used to determine the accuracy that could be expected from its use. Table I gives the value of one standard deviation for different values of contrast and number of observations. The probability that a given contrast calculation will fall within one standard deviation of the true value is 0.54; within two standard deviations, 0.9546; etc. Therefore, one could use this table to make statements such as the following: "The probability is 0.6[illegible] that the true value of contrast lies between 5 percent ± 0.828 percent when one measurement yielded a calculated contrast value of 5 percent;" or we can say "The probability is 0.9546 that the true value of contrast lies between 10 percent ± 0.938 percent when 9 measurements were averaged to yield a calculated value of 10 percent."

Contrast (percent)	Number of Observations				
	1	4	9	16	25
5	0.828	0.586	0.479	0.415	0.372
10	0.809	0.574	0.469	0.408	0.366
15	0.794	0.564	0.463	0.404	0.364
20	0.788	0.556	0.459	0.402	0.364
25	0.765	0.551	0.446	0.404	0.377
35	0.746	0.547	0.464	0.415	0.383

Table I

One Sigma Values for Contrast Relative to Photometer Accuracy

3. Illumination Control

The illumination levels in the Optical Guidance Laboratory and in the pilot display room were maintained through consistent light control settings. Light measurements were made and recorded to ensure precise illumination levels at these settings. The light measurements were made at various fixed points in the laboratory and directly on the targets and their backgrounds.

The changing aspect angle of the photometer relative to the terrain model target areas and targets at various longitudinal ranges in the laboratory resulted in variations in apparent target and area brightnesses for a constant level of illumination throughout the laboratory. The relationship between the target brightness variation and the background area brightness variation was such that the contrast ratio varied significantly with range. Consequently, lighting adjustments (termed "light balancing") were made to compensate for this effect. The final lighting conditions produced consistent contrast ratios over the viewing distances involved; the standard deviation in contrast varied only $\pm$ 0.95 percent about the mean value attained.

4. Contrast

The targets were constructed using metal bases with colored paper fronts; the same colored paint was used on the targets and their immediate background areas. The metal base supported the target on a 45 degree angle and provided vertical alignment pins for exact positioning on the terrain model. The target areas on the terrain model were repainted in their original colors to establish an exact color duplication for the target paper. This paper was painted with an air brush to provide a color consistency across its entire surface. Two-inch square patches of this paper were used for contrast matching with the target background. The 2-inch squares and their background were photometered from the subject's eye position.

The light balancing procedure (discussed in Part 3 above) showed that a target photometered at the 25 foot longitudinal position in the laboratory would have a contrast value very near the mean value of the contrast measured as a function of range. After photometering the basic colored target patch and its background, the brightness of the target patch was adjusted to achieve the required contrast value. This brightness adjustment was accomplished by using a titanium base white paint or a flat black paint as necessary and applying this paint in a very fine mist with an air brush. The targets were then measured at various longitudinal distances as a crosscheck on both light balancing and contrast matching. The actual targets were then made from the matched 2-inch squares. Table II shows the mean contrast values and the standard deviations of these targets. The RSS of the standard deviation and the standard deviation of 0.95 percent contrast variation, attributable to illumination

control as the targets longitudinal positions varies, is shown as the combined standard deviation.

Test 1	Desired Contrast	5	10	15	20	25	35
	Mean Contrast Attained	5.4	10.3	15.5	20.4	24.7	34.9
	Standard Deviation (expressed as contrast)	.7	.5	1.4	1.7	.5	1.1
	Combined Std Deviation (expressed as contrast)	1.2	1.1	1.7	1.9	1.1	1.5
Tests 2,3,4,5	Desired Contrast	10	25	35	50		
	Mean Contrast Attained	10.3	24.7	34.9	50.4		
	Standard Deviation (expressed as contrast)	.5	.5	1.1	.4		
	Combined Standard Deviation (expressed as contrast)	1.1	1.1	1.5	1.0		

Table II

Target Contrasts

5. Flight Variables

a. Altitude

A simulated altitude of 3000 feet was selected as a typical altitude used by reconnaissance aircraft and air-to-ground attack aircraft, on missions requiring target acquisitions, for the following reasons:

1 It is above the range of small arms fire of the .30 cal. variety and is at the extreme end of the range of .50 cal. (14.5 mm) light, portable, rapid-fire arms.

2 It is an optimum "roll-in" altitude for strafing, the delivery of napalm, and retarded weapons (bombs in the 250 and 500 pound classes with specially attached fins that open and allow the aircraft to clear the bomb blast and fragmentation). This altitude can also be used for low altitude rocket delivery although an altitude of 7000 feet and a dive angle of 30 degrees are preferred.

3 Weather conditions in such areas as SE Asia frequently require flight under a 3000 feet overcast.

4 This altitude permits pilots to take quick advantage of terrain masking when operating in a SAM defended environment.

5 Flights lower than this altitude present problems for target acquisition due to terrain masking.

6 This is the same altitude used in the previous experiment and consequently provides similar conditions for comparison of performance between target acquisition of directly viewed targets and of targets displayed on a TV monitor.

This altitude was maintained by placing the subject so that his eye position was at exactly five feet above the target (3000 feet, 600:1 scale).

b. Airspeed

A simulated airspeed of 350 knots was selected as being representative of the speed employed by jet aircraft in the search for ground targets for the following reasons:

1 This speed represents the best tradeoff between fuel consumption and maneuverability for attack type aircraft.

2 The 300 to 350 knot speed range is a preferred speed for starting an attack run.

3 This speed is optimum from the standpoint of ease of aircraft control for formation flying.

4 At this speed, a pilot has sufficient "G" capability to rapidly evade missiles and ground fire.

5 A pilot has sufficient time at this speed to prepare for an attack on the first approach run.

6 This is the same airspeed used in the previous experiment and consequently provides a consistency of conditions for comparison of an operator's target acquisition capabilities.

This speed was simulated by the rate of the longitudinal travel of the terrain model.

H. TEST PROCEDURES

The five experiments conducted in this study were performed, in the Guidance Development Center, using the 40 X 40 foot, 600:1 scale terrain model. The test subjects were briefed on the objectives of each experiment and the procedures to be followed. They were shown the test setup including the terrain model, targets, and briefing material. The test monitor then went over the specific test instructions with the subjects (Appendix B). After answering any questions the subjects had concerning the test, the test monitor seated the first subject on the observation platform in the optical guidance laboratory (Figure 2).

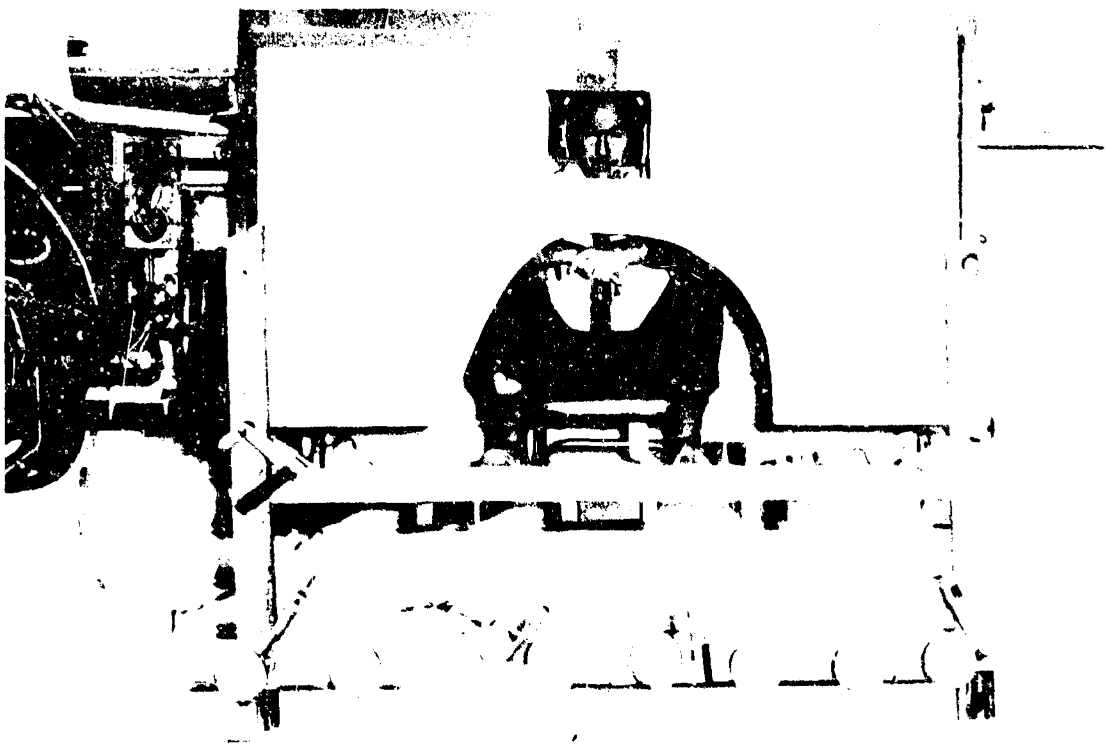


Figure 2. Subject on Observation Platform

The test procedures for the five experiments were basically the same with variations in subject briefing and the dynamic or static target presentation accounting for any differences. Prior to the start of each session, the subjects were given familiarization runs to acquaint them with the experimental procedures.

1. <u>Test 1, Target Acquisition with the Unaided Eye</u> - In this test, the subjects were briefed using 4 by 4 foot plan and oblique photographs of the terrain model (Figures 3 and 4). The 1/2 mile by 1/2 mile target area was marked on the plan view with a grease pencil. The subjects were permitted to mark the oblique photograph if they desired.

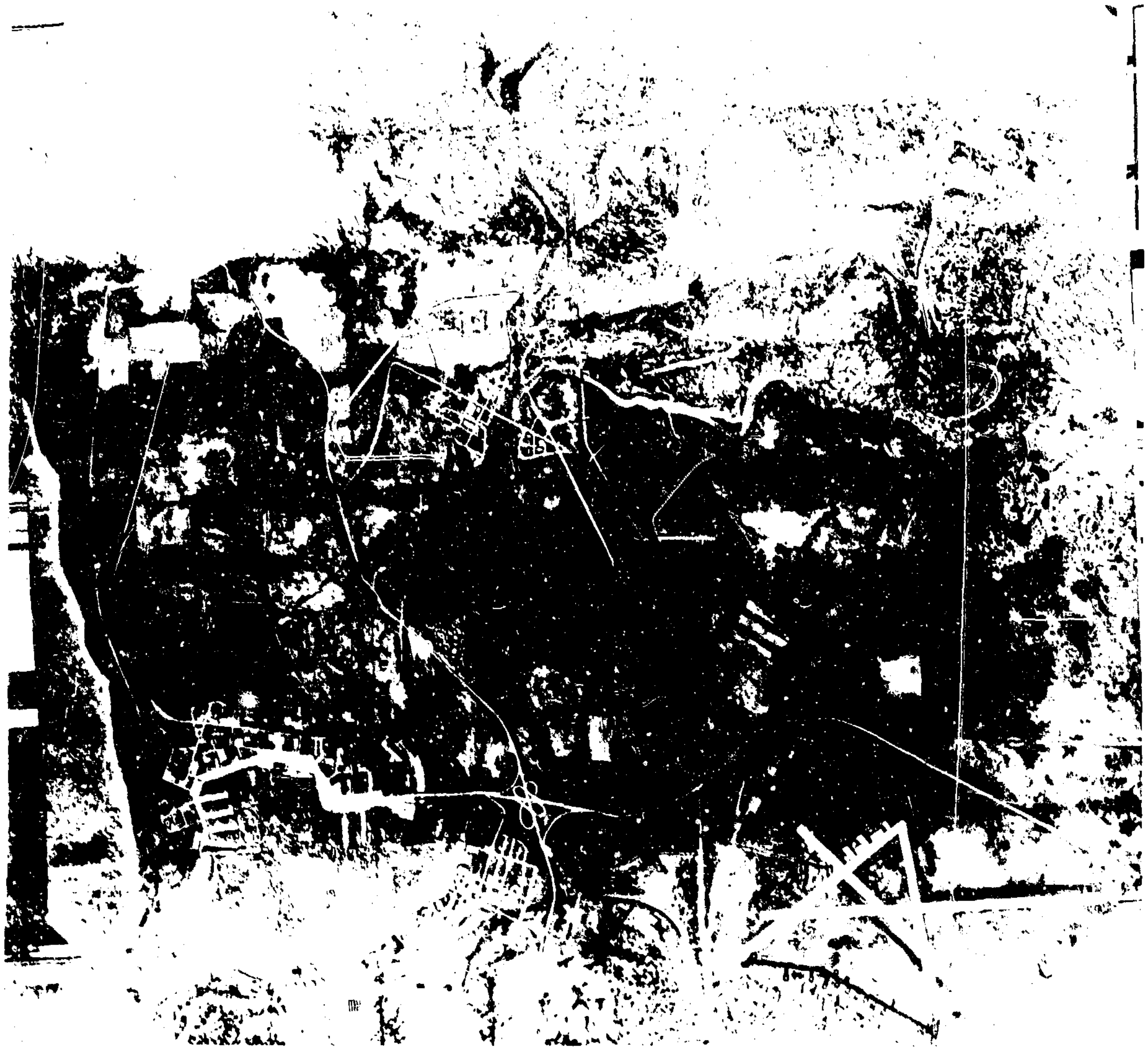


Figure 3. Plan View Photo of Terrain

Figure 4. Oblique View Photo of Terrain

The test sequence was started after the subject was seated on the observation platform and had located the briefed target area on the terrain model. The terrain model moved toward the subject at a simulated 350 knots while the subject scanned the target area. When the subject detected the target he depressed an event mark button which caused the test conditions at that instant to be recorded. At the moment of recognition, the subject again depressed the event mark button and also announced the target shape over the intercom system to the test monitor. At any other time during the test run that the subject made a decision concerning his task he would depress the event mark button and state his decision, e.g., the realization of a false detection or false recognition.

At the conclusion of each test run, the subject would return to the briefing room to prepare for the next run.

2. Test 2, Determination of the Target Detection Threshold for the Unaided Eye, Dynamic Mode - Procedures for this test were similar to those used in Test 1, except that the size of the target area was reduced and target recognition was not required. For this test, the terrain model movement toward the subject was stopped by depressing the event mark button when the subject signalled a detection. The subject was then required to describe the precise position of the detected target to the satisfaction of the test monitor.

3. Test 3, Determination of the Target Detection Threshold for the Unaided Eye, Static Mode - The experimental procedures were the same for this test as for Test 2, above, except for the static positions of the target. The target was positioned at the maximum range, minimum subtended angle, and the range was closed in increments which produced one-tenth of an arcminute variation in the subtended angle between each position. The subjects were allowed to observe the target area at each position for as long as they desired before moving to the next position.

4. Test 4, Determination of the Target Recognition Threshold for the Unaided Eye, Dynamic Mode - In order to determine the desired target recognition threshold, this test started with target detection accomplished by having the exact target position marked on the briefing photographs and by having the target pointed out on the terrain model by the test monitor. The terrain model then closed range at the simulated 350 knot speed until the subject signaled target recognition by depressing the event mark button and reported the target shape to the monitor.

5. Test 5, Determination of the Target Recognition Threshold of the Unaided Eye, Static Mode - The experimental procedures were the same for this test as for Test 4, above, except for the static positions of the target. The target was positioned at the maximum range, minimum subtended angle, and the range was closed in increments which produced one-tenth of an arcminute variation in the subtended angle between each position. The subjects were allowed to observe the target area at

each position for as long as they desired before moving to the next position.

I. SUBJECTS

The subjects required for these tests were selected on the basis of previous military aviation experience in target acquisition. All of the subjects selected were ex-military pilots and their experience is outlined in Table III. The broad experience of these subjects includes visual reconnaissance and air-to-ground attack missions. One subject served a combat tour in the Vietnamese conflict. It was hoped that the use of experienced pilots would contribute to the validity of the data and its application to operational requirements.

The subjects were given eye examinations by the Martin Marietta Medical Department to ensure that they have normal or in the case of visual acuity, corrected to normal vision. The tests given were:

1 Ishihara test for color blindness.

2 Near and far distance visual acuity tests using a Bausch and Lomb Orthorater.

Subject	Service	Aircraft Flown	Jet Hours	Total Hours
1	USAF	A1E, F4C	1100	1130
2	USN	PBY, P2V	3	4000
3	USMC	Many types including A4D	500	5000
4	USAF	P-51, F-86, F-100, F-101	2100	5600
5	USAF	B-24, B-47	1000	6000
6	USAF	P-40, P-51, P-47, F-80, F-86, F-100	2000	4000

Table III

Subjects' Flight Experience

II. STATISTICAL ANALYSIS OF RESULTS

An analysis of variance (AOV) (Reference 5) was performed to determine the basic statistical relationships between the test parameters. The Duncan Multiple Range Test (DMRT) (Reference 10) as well as individual t-tests were used to determine detailed relationships at test points indicating significance on the AOV.

The results are discussed according to the separate objectives: the investigation of target search, detection and recognition in unbriefed and briefed modes and the determination of static and dynamic threshold values for target detection and recognition. General findings common to all five tests, including effects of contrast on visual angle and slant range, are presented first in an overview.

Performance as a Function of Contrast

Table IV shows the analysis of variance for all five tests with the tests treated as blocks. Test 1, the search task over the briefed 1/2 X 1/2 mile target area, was partitioned into two separate tests: detection and recognition. Differences in levels of contrast between Test 1 with six levels and Tests 2 - 5 with four levels dictated a compromise on the analysis of the contrast main effect. For this combined AOV, the same three levels of contrast common to all five tests were used: 10, 25 and 35 percent.

Additional AOV's were computed for each test separately and the Duncan and t-tests were performed on these data since there were additional contrast levels which could be analyzed. These AOV tables are presented in Appendix C.

As expected, the variation in performance due to changes in the target-to-background contrast levels was the strongest effect. At low contrast levels the threshold distances for slant range at detection or recognition were the smallest and increased with an increase in contrast up to approximately the 20 percent level where they leveled off. Converting these values into visual angle subtended by the target at detection and/or recognition, the ability of the operator to see the target increased (a decrease in required visual angle) with an increase in contrast up to the same 20 - 25 percent level and then was constant as contrast increased. In all cases contrast was not a significant factor at levels of 25 percent or above.

Source of Variation	df	SS	F
Blocks (B)	5	92.51	59.30 **
Subjects (S)	4	21.49	17.22 **
Targets (T)	2	2.27	3.64 *
Contrast (C)	2	87.48	140.20 **
B X S	20	13.49	2.16 **
B X T	10	5.62	1.80 N.S.
B X C	10	26.15	8.38 **
S X T	8	2.51	1.00 N.S.
S X C	8	5.67	2.27 *
T X C	4	7.02	5.63 **
B X S X T	40	8.94	0.72 N.S.
B X S X C	40	12.93	1.03 N.S.
B X T X C	20	25.28	4.05 **
S X T X C	16	7.08	1.42 N.S.
Residual	80	24.96	
Total	269	343.40	

Table IV

Combined Analysis of Variance Tests 1 - 5

*$P < .05$
**$P < .01$

The greatest variation in performance due to contrast was at the 5 - 15 percent levels as shown in Figure 5. This graph illustrates the overall effects of contrast on visual angle for all five tests including the detection and recognition phases of Test 1. Vertical brackets at each contrast level denote non-significance of performance results compared across each test as computed by either the DMRT or t-test.

In order to compensate for missing data due to errors and lack of subject response, values of extremes and values of means were used for those missing data cells. AOV's were computed with both sets of values. Test results were unaffected, i.e., there were no significant differences resulting from use of either set of values except at the 5 percent contrast level on the detection phase. Both the extreme values and mean values were different ($p < .01$) from the dynamic recognition phase of the test. At all other contrast levels no significant differences occurred between the detection and recognition phases of the test except at the 35 percent level (significant at $p < .05$).

This indicated that, at the higher contrast levels, recognition occurred almost simultaneously with detection of the target. Results of the DMRT across contrast levels revealed that there was not a significant difference between the 5 percent and 10 percent points but that these two were different ($p < .05$) from all other contrast levels. The levels from 15 - 25 percent were not different from each other indicating that, at higher contrast levels, contrast apparently had little effect on detection and/or recognition for tasks involving search or threshold acquisition. The simulated slant range at detection occurred from more than 24,000 ft out for the 20 percent down to greater than 16,000 ft at the 5 percent level.

<u>Test 1: Target Recognition</u>

The same pattern was evident in the recognition phase as it was in the detection phase. Recognition of the target became easier as the contrast increased to the 15% level and then leveled off. Unlike the detection phase, recognition became increasingly easier from the 5 percent contrast level thru the 15 percent level. This indicated that even the extreme value substitutions in Phase 1 were on the conservative side and could have been higher.

The difference at the 35% level ($p < .05$) between detection and recognition may have been a type I error, or it may have indicated a trend toward significantly earlier detection prior to recognition.

Tests 2 thru 5 examined target detection and recognition thresholds by:

1 Eliminating the search requirement. The subject was shown a very small target area to be detected (its visual angle was approximately 2.4°) and he was given an exact position briefing; the target

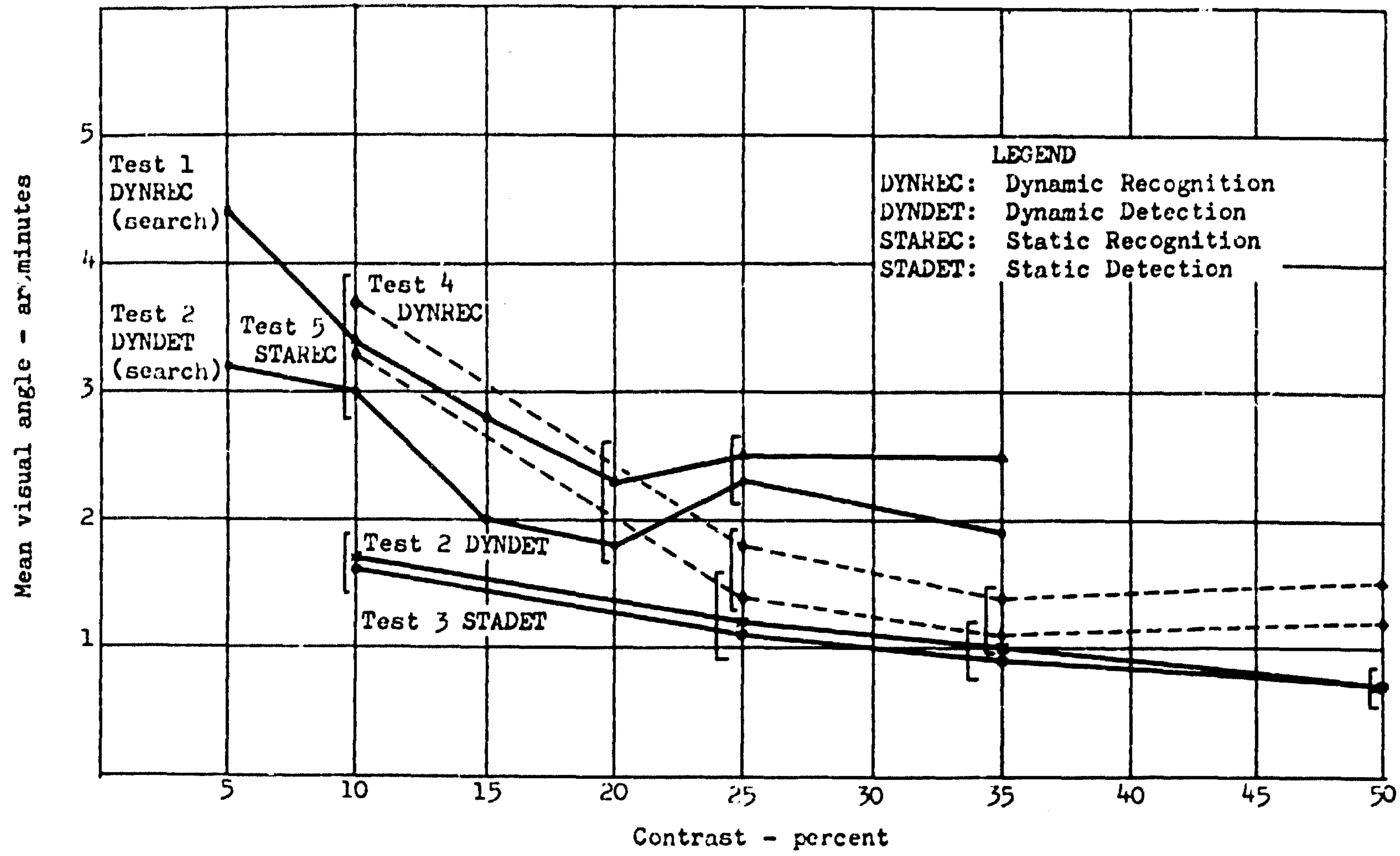


Figure 5. Target Detection and Recognition as a Function of Contrast

itself was pointed out for the recognition threshold tests.

2 Eliminating the effect of decision time on both detection and recognition. The subject was given unlimited viewing time during the static tests.

Tests 2 and 3: Dynamic Detection and Static Detection - Briefed Targets

The threshold detection and recognition tasks showed no significant differences due to the time a subject viewed the target. There were no differences between Test 2, Dynamic Detection and Test 3, Static Detection, at any contrast level (Figure 5) showing that test conditions eliminated the search element. Detection slant range differences between the dynamic and static cases ranged from 1200 ft at the 50 percent contrast level to 4100 ft at the 25 percent level.

The effect of contrast on visual angle was greatest at the 15 percent level. There was no difference, however, between the 25 percent and 35 percent levels or the 35 percent and 50 percent levels. A trend of increasing effectiveness of contrast was indicated by the difference between both the 10 and 25 percent levels compared to the 50 percent level.

The effect of limiting the search requirements to a very small area was evident in comparing Test 2 with Test 1 (see Figure 5). There were significant differences ($p < .01$) at all contrast levels between these tests. Differences in slant range varied from 3000 ft at 10 percent to 7400 ft at the 35 percent level. Differences in detection time ranged from a minimum of 5.1 seconds difference at 10 percent to 12.5 seconds difference at the 35 percent level.

A direct correlation with slant range was the visual angle of the target subtended at the eye. This analysis showed a visual angle of 3.0 arcminutes required for search at the most difficult contrast level of 10 percent as compared to 1.7 arcminutes of angle for the non-search task of Test 2. At the maximum level of 35 percent, Test 1 required a visual angle of 1.9 arcminutes while Test 2 requirements were half that or 1.0 arcminutes.

Where there was very little difference between detection and recognition on the search task (Test 1), there was a great difference between these factors at the threshold level. Test 2, Dynamic Detection and Test 4, Dynamic Recognition, were significantly different ($p < .05$) at all contrast levels except the 35 percent level. At the 10 percent level, recognition did not occur for 17.3 seconds, or at 10,200 ft slant range, after detection which occurred at 20,500 ft. At the 50 percent contrast level, the subject waited an average of 48.9 seconds or traveled an additional 28,900 feet, on the average, before recognition occurred.

Tests 4 and 5: Dynamic and Static Recognition

The only significant difference between static and dynamic conditions in Test 4 and 5 was at the 50 percent contrast level (See Figure 5) where the two were just different at the .05 level.

The static and dynamic cases maintained a minimum difference of 1100 ft at 10 percent contrast and 6900 ft at the 35 percent level. Following the trend of all other test conditions, contrast did not have an effect on recognition after the 25 percent level. At low contrast levels the elimination of the search requirement did not affect performance as shown by the lack of statistical difference between Test 1 and Test 4. As the targets became easier to see, however, the recognition thresholds were much lower than for the search task (Test 1) e.g., 2.5 versus 1.8 arcminutes of visual angle at 25 percent contrast and 2.4 versus 1.4 at 35 percent. This converts to 14,300 ft versus 19,000 and 14,300 ft versus 24,500 ft slant range respectively.

III. DISCUSSION OF RESULTS

A. DETECTION

Figure 6A shows the relationship between the search and threshold phases of the detection task with respect to the visual angles obtained. There was a large decrement in performance at low contrast levels on this task due to the search requirement, and the difficulties involved in finding the target. As the targets became easier to see at the 20 - 25 percent levels, the difference in performance between the search and threshold tests became constant. The search component required approximately 1.1 arcminutes of visual angle more than did the threshold task. The improvement in subject performance on the threshold task appeared to be a linear function throughout the contrast range. Search at the low contrast levels required a target size of from 1.2 to 2.0 arcminutes larger than the threshold values of 1.4 to 1.8 arcminutes. When these are converted to slant ranges, search appears to become linear (Figure 6B) over the total contrast range with detection occurring at 10,000 feet at 5 percent contrast up to 22,000 ft at the 50 percent level.

Threshold detection, however, improved greatly at the higher contrast levels up to a maximum detection range of 48,000 ft at the 50 percent level.

In summary, the effects of target-to-background contrast on a search task is such that at low contrast levels, a constant difference exists between the requirements for threshold detection and search detection. This was approximately 9000 - 10,000 feet slant range and at the simulated aircraft speeds would amount to a time differential of 15 seconds. Consequently, pinpointing low contrast targets during a briefing would allow an attack pilot up to 15 additional seconds to align his aircraft with the target over that available when target search is required.

B. RECOGNITION

Figures 7A and 7B illustrate the relationship of contrast to visual angle and slant range for the recognition tasks. At low contrast levels, search was masked by the inherent difficulties in seeing the target at all. Therefore, any significant difference between search and threshold functions did not appear until the contrast levels reached 20 percent.

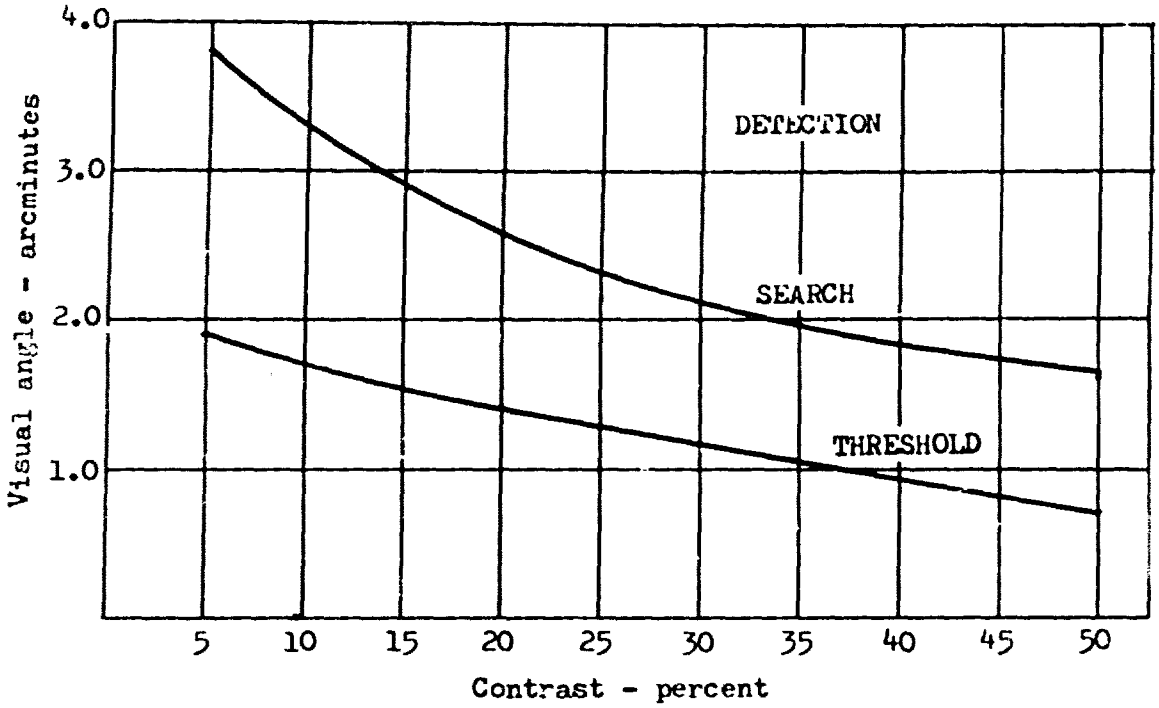


Figure 6A. Visual Angle as a Function of Contrast for Detection

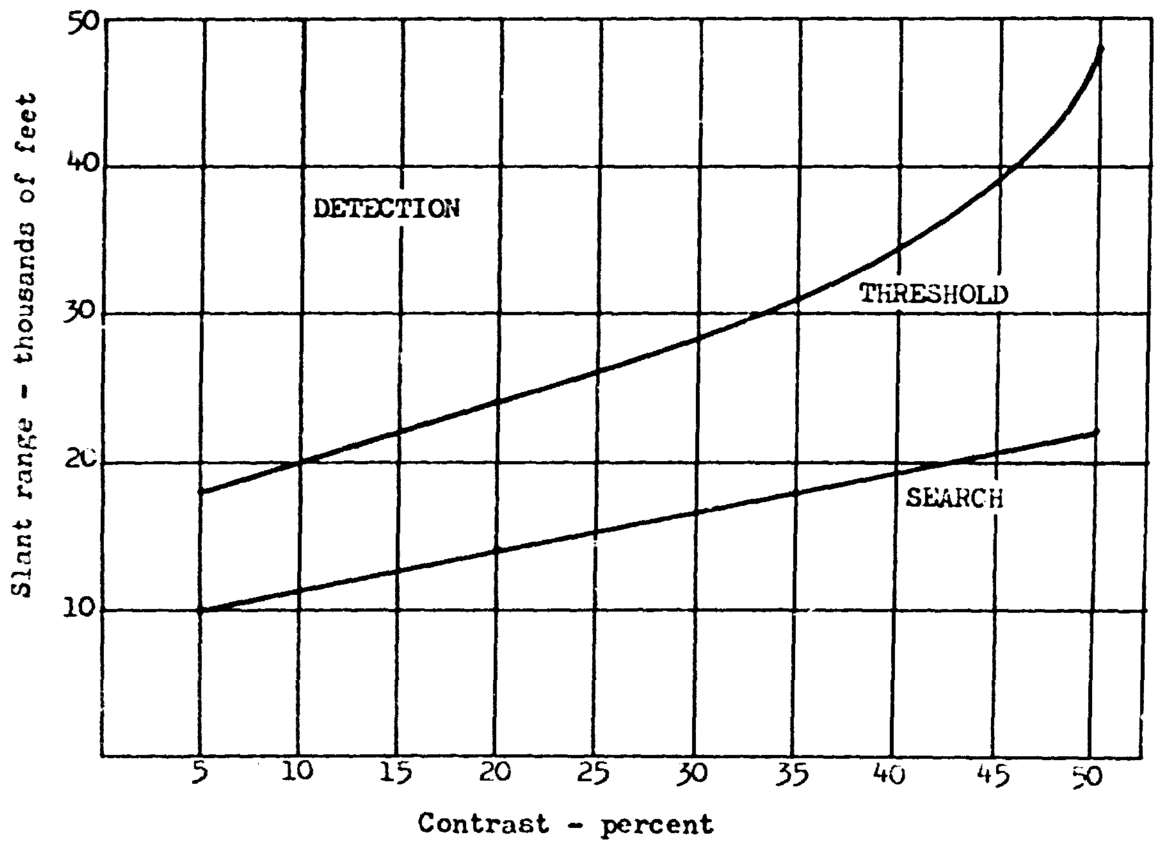


Figure 6B. Slant Range as a Function of Contrast for Detection

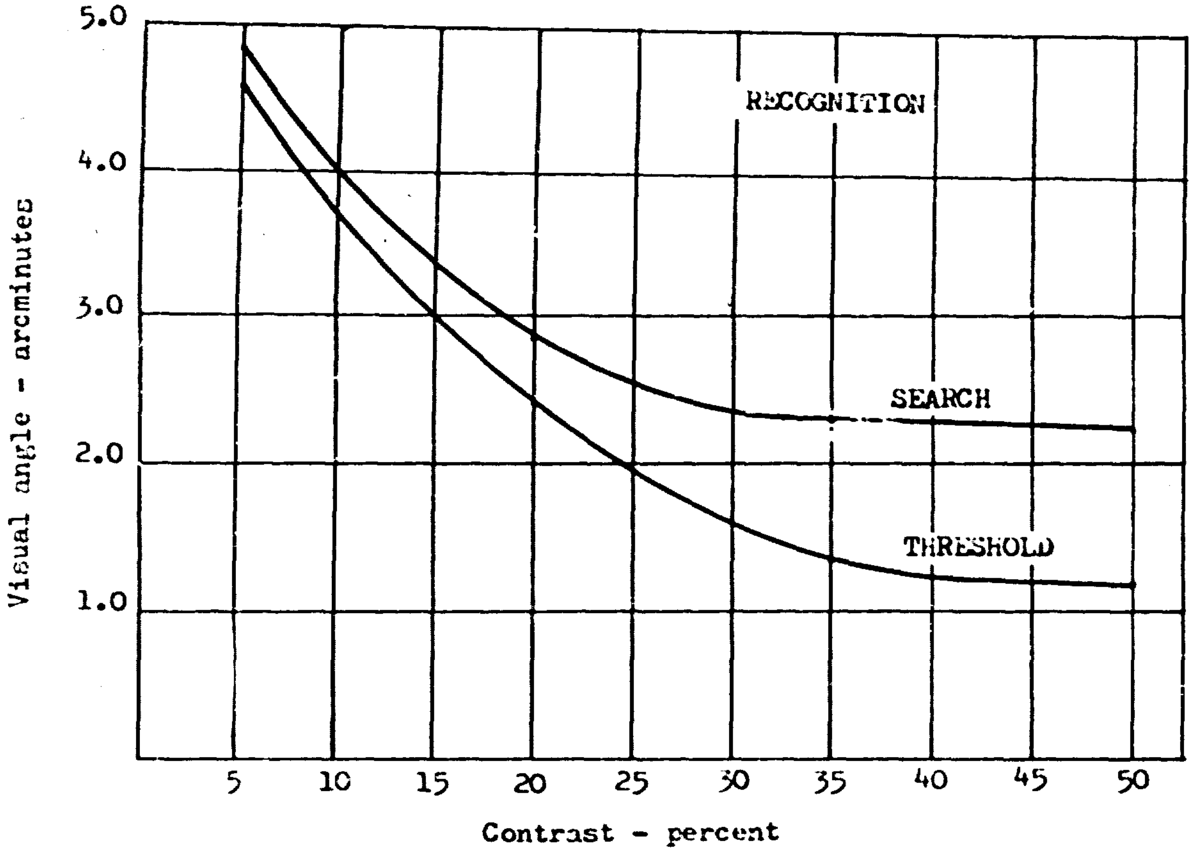


Figure 7A. Visual Angle as a Function of Contrast for Recognition

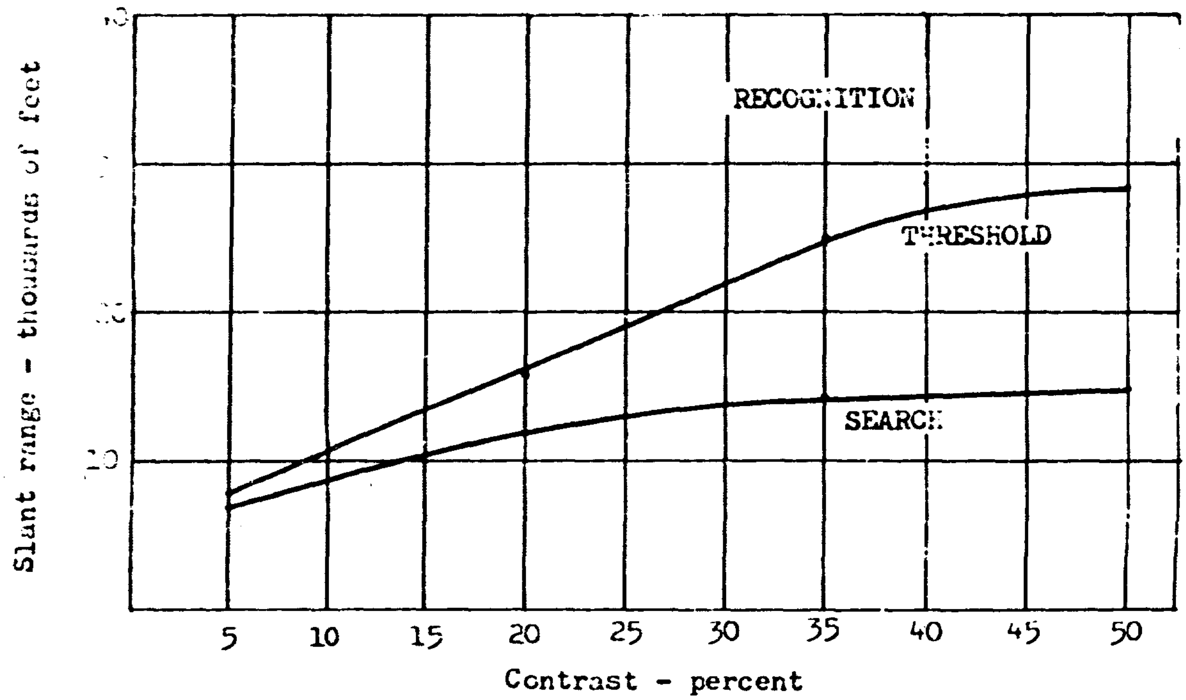


Figure 7B. Slant Range as a Function of Contrast for Recognition

Converting to slant ranges, at the lowest contrast level, recognition of the target did not occur until 7000 feet. This would leave almost no time to release and guide any type of steerable ordnance. The maximum recognition slant range on these studies was 15,000 feet which could be considered close to a minimum release point for steerable ordnance.

C. TIME DEPENDENT RESPONSES - STATIC VS DYNAMIC CONDITIONS

Unlimited response time had no effect on whether a subject could detect or recognize a target throughout the total contrast range. A constant difference existed between the dynamic and static detection tests as well as the dynamic and static recognition tests, however, these were not statistically significant. These differences appeared to be due to subject reaction time.

D. SUBJECT VARIABILITY

In all tests, the subject main effect was statistically significant at either the .01 or .05 levels, but graphical analysis indicated that this effect was attributable to individual differences in the five experienced pilots. There were no consistent trends, however, and analysis of subject X target and subject X contrast interactions which were evident in two tests, indicated only variability and no trend data. The percentage of mean square versus error variability varied from 6 percent to a high of 26 percent on the detection portion of Test 1. All of the test subjects had participated in earlier tests and were considered highly experienced. No improvements in performance due to training or learning factors were evident.

APPENDIX A

DESCRIPTION OF FACILITIES

A. OPTICAL GUIDANCE LAB

The Martin Marietta Guidance Development Center is composed of the Radar Guidance Lab (not used in this study) and the Optical Guidance Lab. Both of these labs are housed under one roof and, because of their compatible requirements, share equipment and support personnel. Some orientation to the GDC and the OGL (hereafter referred to as the GDC) can be obtained by referring to Figure 8. The maximum design characteristics of the GDC are shown in Table V.

	Displacement	Velocity	Acceleration
Long	± 110 ft	0 - 10 ft/s	0 - 8 ft/s^2
Vert	0 to 24 ft	0 - 6 ft/s	0 - 6 ft/s^2
Lat	± 19 ft	0 - 4 ft/s	0 - 2.7 ft/s^2
Pitch	± 120 deg	± 200 deg/s	2000 deg/s^2
Yaw	± 45 deg	± 200 deg/s	2000 deg/s^2
Roll	Continuous	± 750 deg/s	8000 deg/s^2

Table V

Laboratory Maximum Design Characteristics

The simulation of flight and range closure is accomplished in the GDC by 1) the three rotational degrees of freedom provided by the gimbaled flight head, 2) the lateral and vertical motion of the flight head on the beam carriers, and 3) the longitudinal closing of the terrain model.

The objectives of this experiment were restricted to testing using the human eye as the only sensor. As a result, only the longitudinal closing motion of the terrain model was employed to simulate flight.

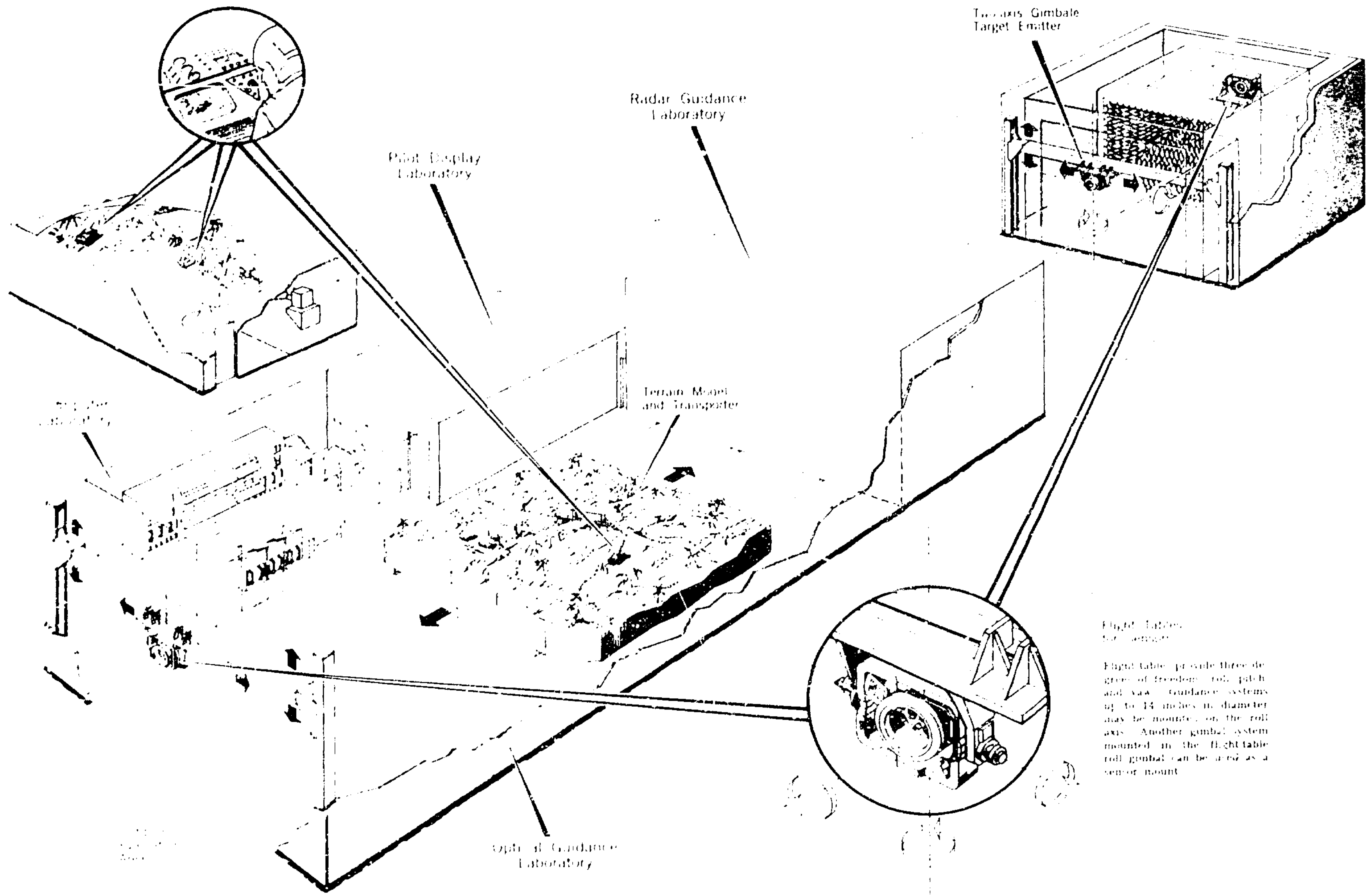


Figure 6. Guidance Development Center

B. TERRAIN MODEL

The terrain model is a 40 foot square, three dimensional-target model simulating natural and man-made features of particular military significance. Typical of the many tactical targets provided are the hydro-electric plant, Vietnamese type village, an airport and harbor area with oil dump and train marshalling yard. Target features have been reproduced at a scale of 600:1 and contain minute detail. The model can be rotated in azimuth in 90 degree increments to provide better use of the available terrain when used in studies involving search over unknown areas. The model can also be tilted with respect to the horizontal plane at an angle to simulate larger depression angles. Controlled illumination is provided indoors, but the model may be moved outdoors to take advantage of natural illumination. Figure 9 shows the model near the end of a test run.

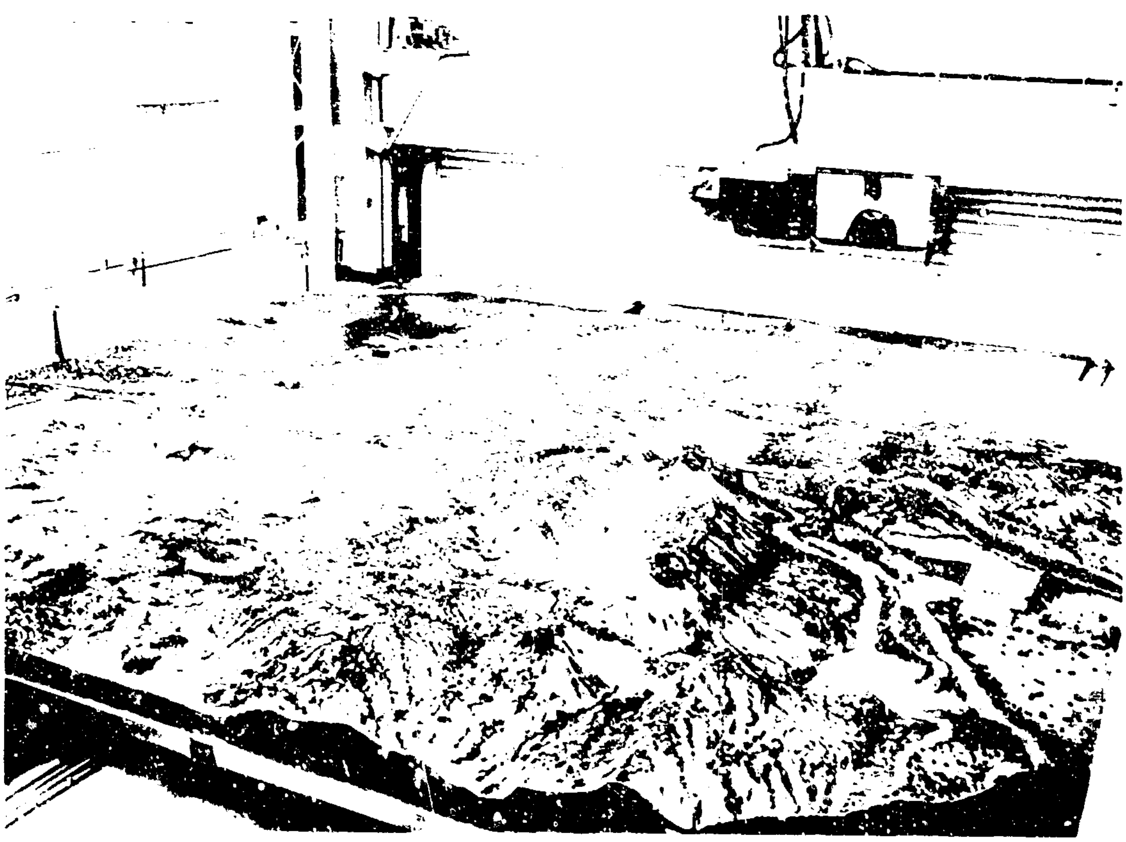


Figure 9. Terrain Model During Test Run

Typical model parameters are given in Table VI.

	6[illegible]:1 Scale		
	Displacement	Velocity	Acceleration
Long	11 mi	6000 ft/s	150g
Vert	12,000 ft	3600 ft/s	112g
Lat	4 mi	2400 ft/s	50g

Table VI

Typical Model Parameters

Some typical targets and target area locations used in this study are shown in Figures 10 and 11.

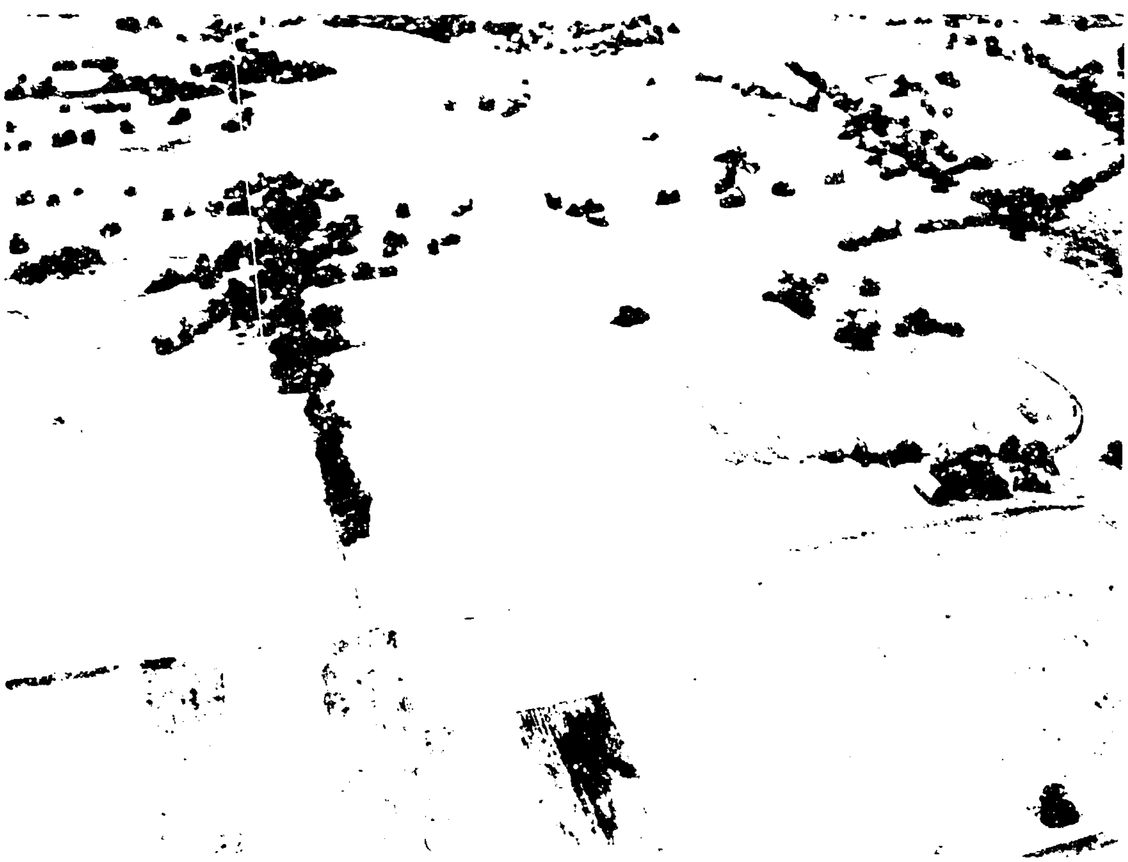


Figure 10. Typical Target Area Location Showing House Target

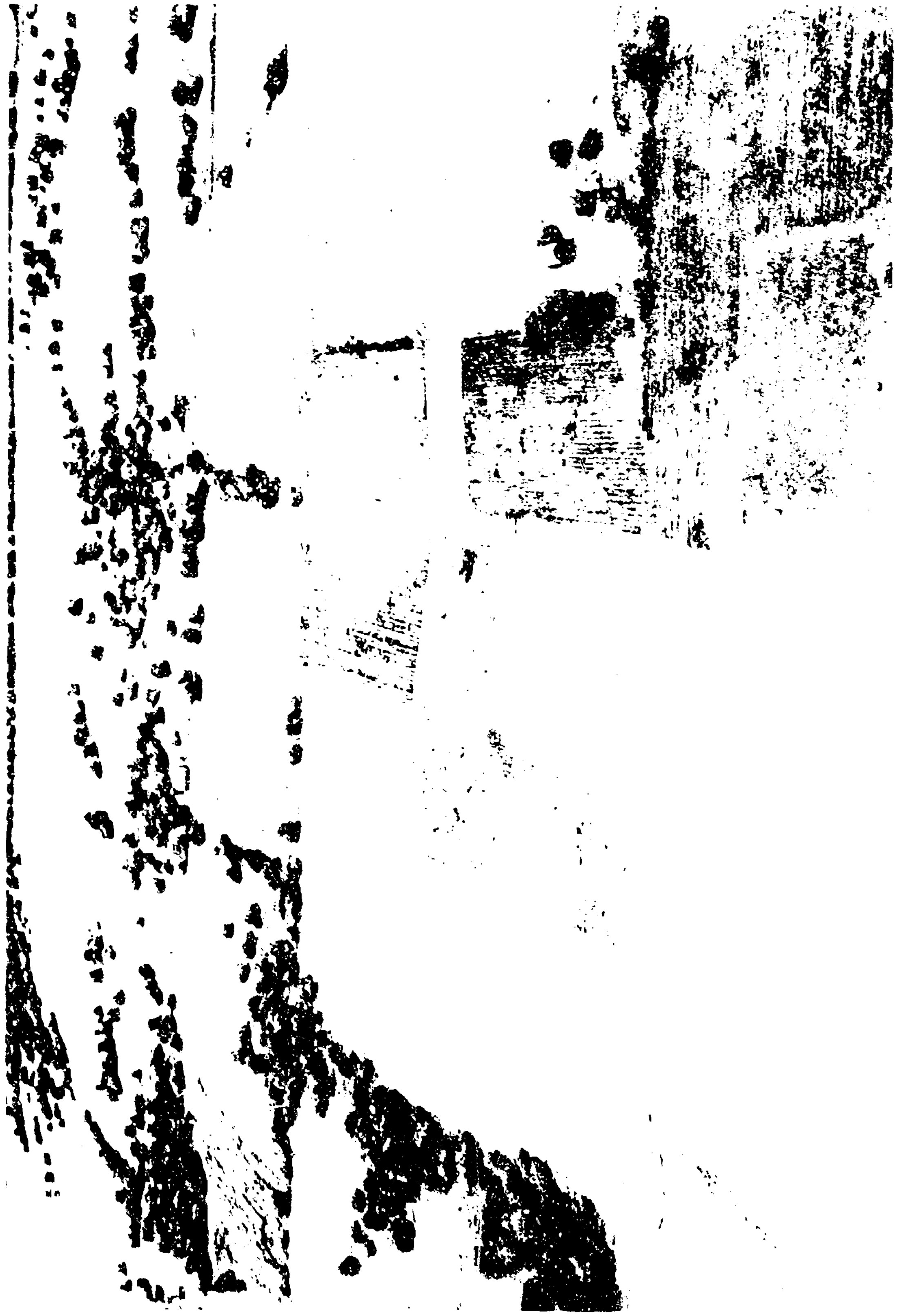


Figure 11. Typical Target Area Location Showing Right Shed Target

C. AMBIENT LIGHTING SYSTEM

The GDC has a basic ceiling lighting system made up of a combination of fluorescent and incandescent sources (Figure 12) and is divided into six bays. Each bay of fluorescent lights is controlled in 50 FC increments, and each bay of incandescent lights is continuously variable from zero to maximum. With this type of lighting, a wide variety of illumination profiles may be generated. Illumination levels of approximately 250 to 400 FC, measured at the model surface, were used for this study.

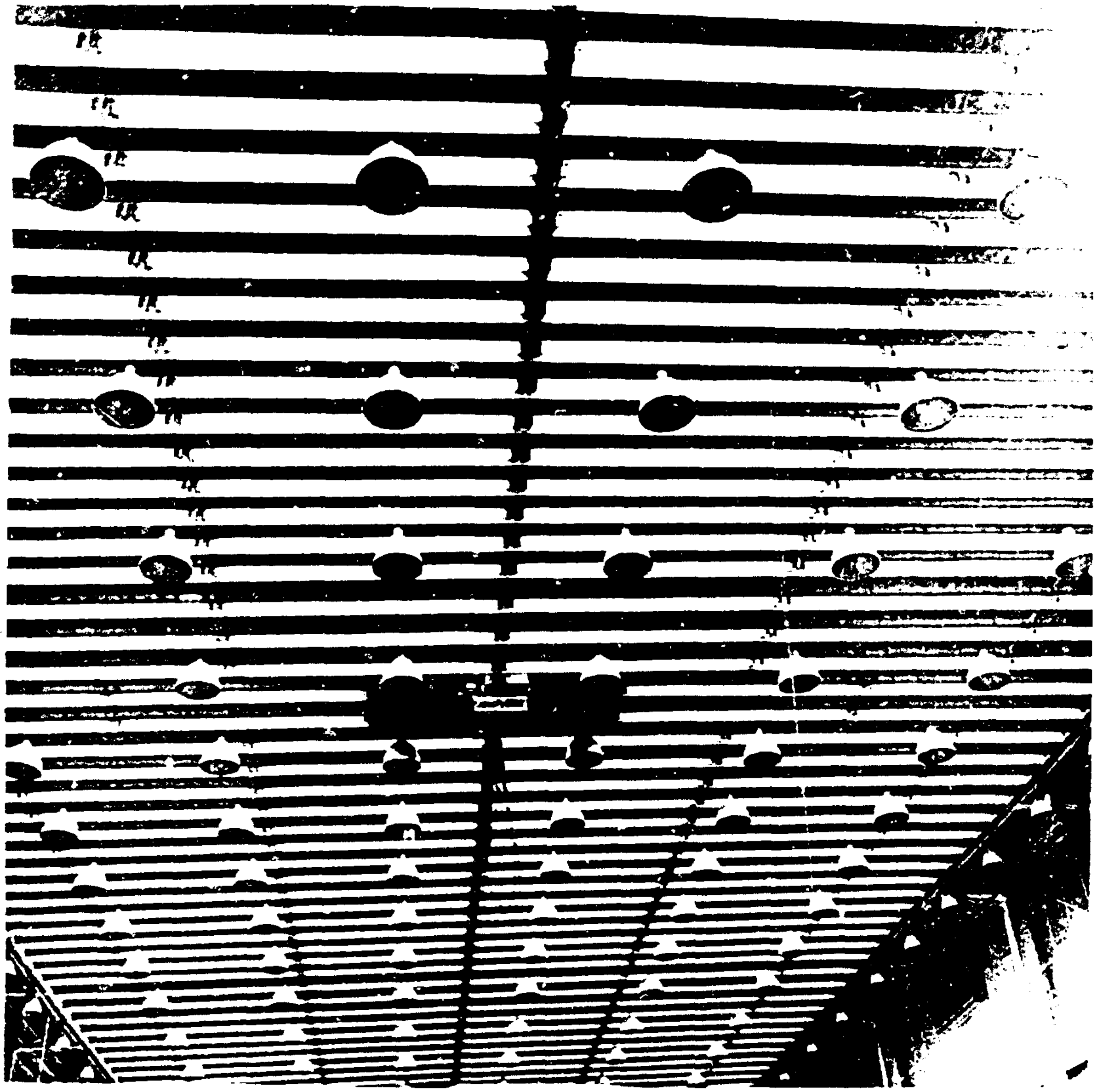


Figure 12. GDC Ceiling Lighting System Showing Fluorescent and Incandescent Fixtures

Figures 2 and 9 on pages 17 and 35 respectively, show the auxiliary lighting mounted under the observation platform used to solve the problem of nonuniformity of illumination at the very end of the run. The non-uniformity, when measured with a ft-candle meter at a point on the model, looked like the top curve in Figure 13 while the auxiliary lighting, produced the lighting effect on that same point as shown by the bottom curve. The resultant brightness level produced the desired control of target-to-background contrast.

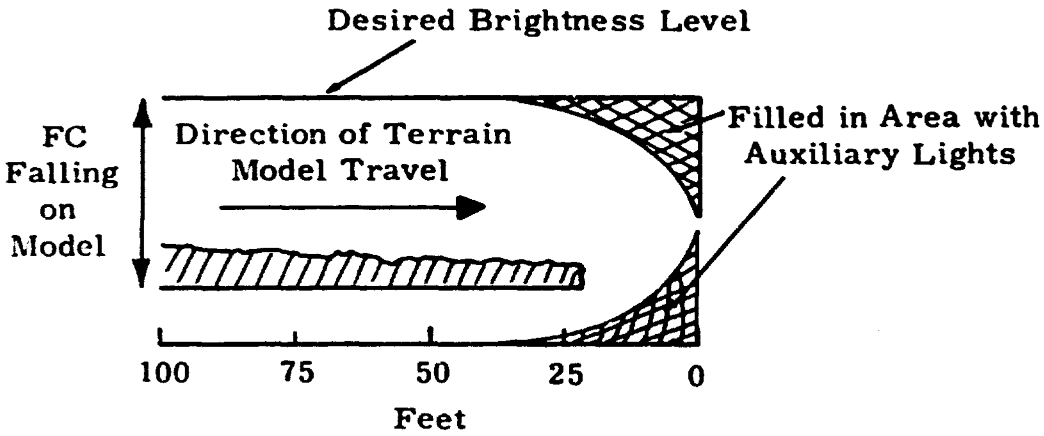


Figure 13. Illustration of Filler Lighting Scheme

The successful solution to this problem was mandatory since the 45 degree targets used were highly sensitive to a fall-off in frontal illumination. This type of fall-off kept the background roughly the same brightness, but caused the face of the target to darken at a more rapid pace than did the background. This then caused a change in contrast that was not acceptable. By carefully adjusting the auxiliary lights, contrasts could be held within test tolerances throughout the run.

D. DESCRIPTION OF CONTROL AND RECORDING EQUIPMENT

The analog computer used during this study was an EAI PACE 231R. An 8-channel EAI strip chart recorder was used in conjunction with the computer to obtain a permanent record of the data and the variables pertinent to the analysis of the problem. Figure 14.

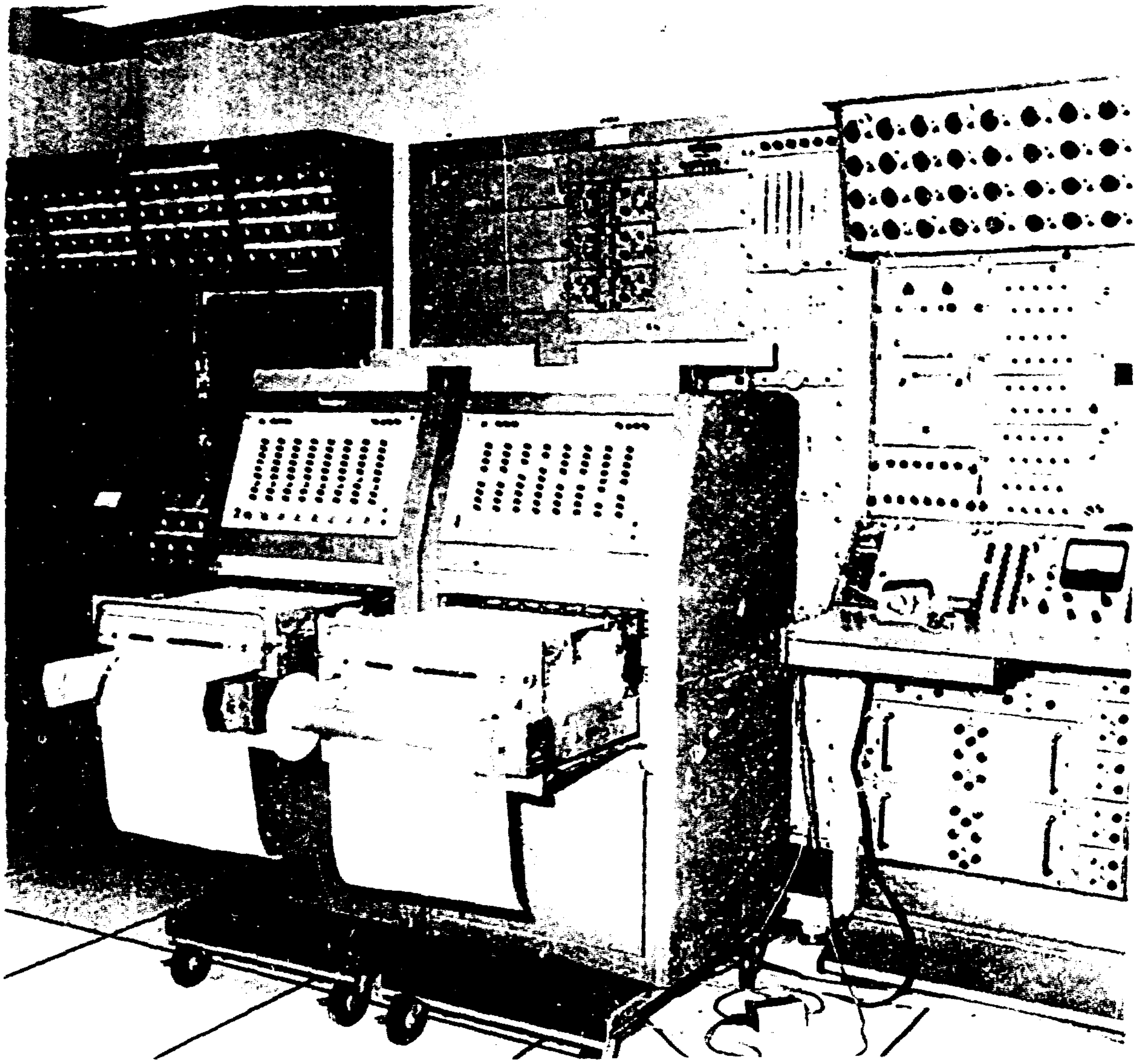


Figure 14. Analog Computers and Recorders Used in GDC

The manual positioning of the terrain model and observation platform was accomplished by manually adjusting potentiometers while monitoring the voltages from feedback potentiometers located on the various drive units. Figure 15 shows the manual drive consoles and lighting control panels.

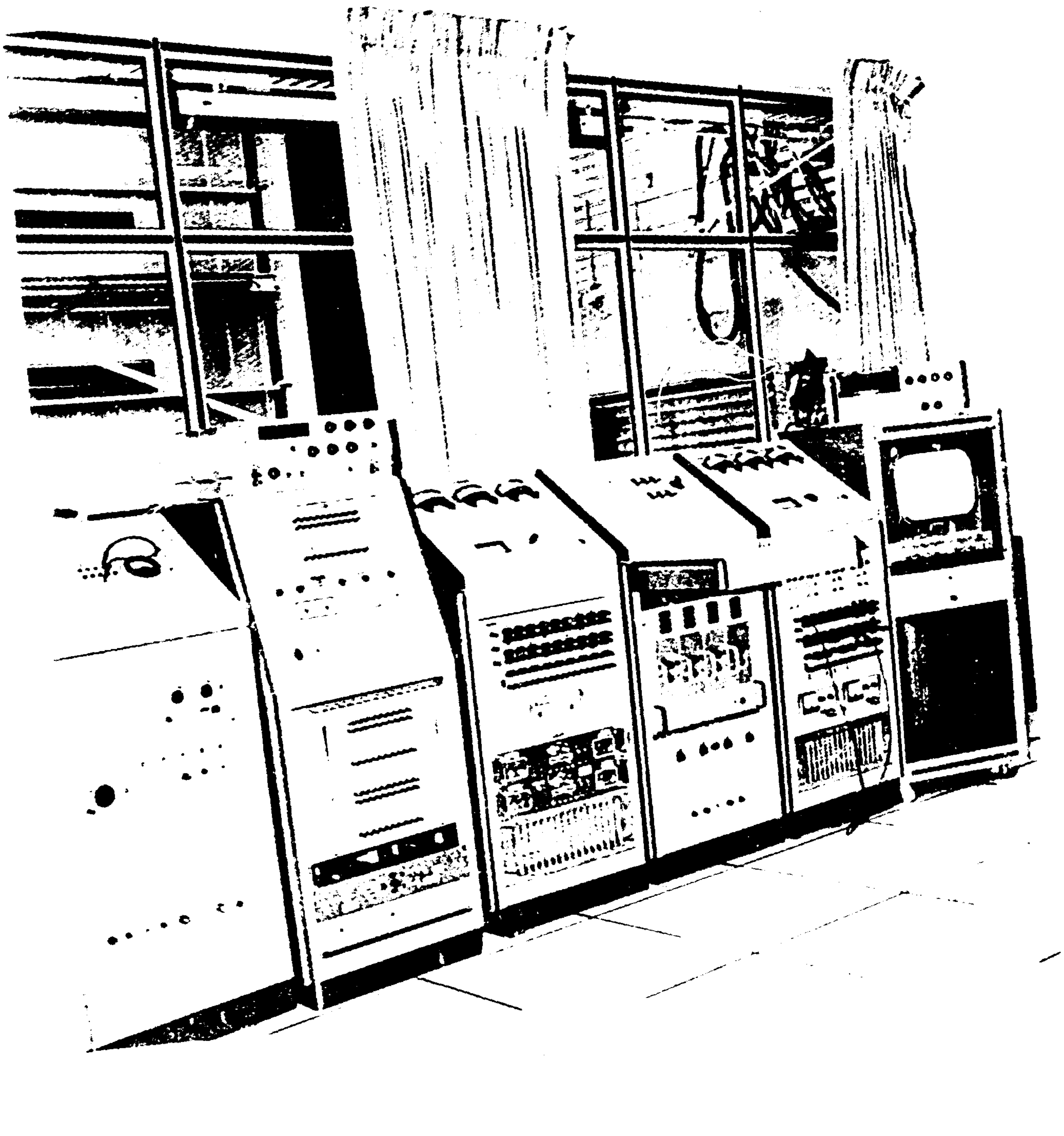


Figure 15. Manual Drive Consoles and Lighting Control Panels

APPENDIX B

SUBJECT INSTRUCTIONS

Prior to each test, the subjects were briefed on the general and specific objectives of the experiment and given a copy of the instructions shown below. These instructions and the test procedures were discussed until the test monitor was assured that each subject understood his task.

INSTRUCTIONS - TEST 1

TARGET ACQUISITION WITH THE UNAIDED EYE

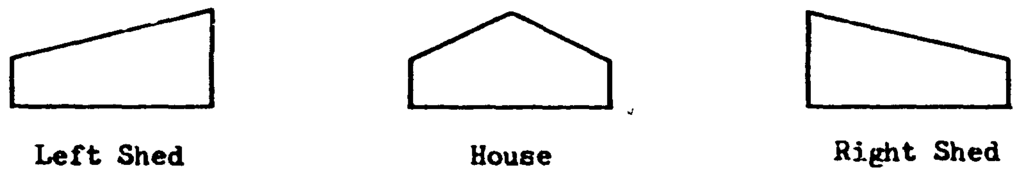
1. The purpose of this experiment is to determine the ability of specially qualified subjects to acquire surface targets from the air under various experimental conditions.

   The experiment will simulate the flight path of an attack aircraft flying towards a pre-briefed square shaped target area 0.5 miles on a side at 350 knots and 3000 feet altitude. The basic task of the test subjects will be to locate the target in the target area and report target detection and recognition as it occurs.

   The aircraft flight will be towards the center of the target area as shown on the briefing photographs. The briefing photographs are both vertical and oblique views of the terrain model with the target area marked on the vertical view.

   Prior to each run, you will have time for briefing using photographs of the terrain with the target area outlined. Your task during briefing will be to familiarize yourself with the target area.

   The targets used during this experiment are representative of targets 37.5 feet long and 18.75 feet high. The targets are two dimensional and inclined at a 45 degree angle to overcome the variations induced by shadows and to maintain a constant target presentation during the entire run. The shapes which are being used are shown below.



The runs will be made from approximately 7 miles slant range to 2 miles, simulated.

Procedures

1. As soon as you arrive for the scheduled session, refer to the schedule posted in the briefing area and determine which target area applies for your first run.

2. Study the appropriate target area on the briefing photographs.

3. When it is your turn to take a run, you will be seated on the platform in the lab area. When the platform has been positioned for the run, you will be notified over the intercom and you should then locate the target area as marked on the briefing photograph.

4. As soon as you are ready to start the run, notify the experimenter via the intercom.

5. After the run has started, scan the target area in search of the target.

6. Press the event mark button immediately upon detecting the target. The definition of target detection will be considered here to be that point when you feel that you have sufficient information concerning the suspected target such that you would, if flying, alter your flight path in order to better verify the existence of the target.

7. Press the event mark button a second time immediately upon recognizing the target. Recognition is considered to occur when you have sufficient information concerning the target such that you would be willing in an operational situation, to commit yourself to weapon release at the earliest possible time while also being able to describe the target by name. Announce the name of the target to the experimenter.

   In the event that detection and recognition occur simultaneously, press the event mark button and announce the name of the target to the experimenter. If you realize that an error in either detection

or recognition was made, press the event mark button to indicate your corrected detection and/or recognition response, announce the fact to the experimenter and continue as before.

Remember - always press the event mark button immediately upon making a detection or recognition decision. The verbal statements will always follow the "event mark."

8. At the conclusion of the run, return to the briefing room and prepare for your next run.

9. During the course of each session, please do not disclose to the other subjects any information relative to your findings or observations during a run. A comment may seem harmless relative to the experiment but it could help or hinder another subject and as a consequence, bias the results.

Do not hesitate to ask questions of the experimenter concerning your individual performance or any procedures.

Prior to the actual test runs, there will be familiarization runs to acquaint you with the experimental procedures.

INSTRUCTIONS - TEST NO. 2 AND 3

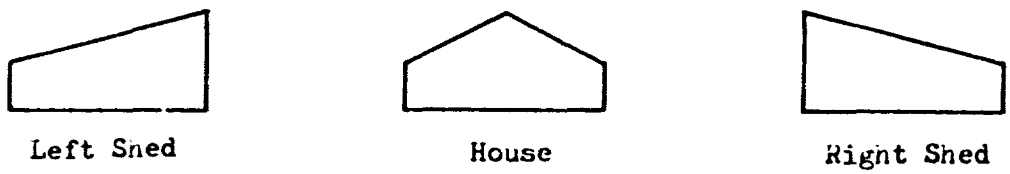
DETERMINATION OF THE TARGET DETECTION THRESHOLDS OF THE UNAIDED EYE, DYNAMIC AND STATIC

1. The purpose of this experiment is to determine the target detection capability of specially qualified subjects.

   The two tests will simulate the flight path of an attack aircraft flying towards a pre-briefed 600 foot diameter circular target area at 350 knots and 3000 feet altitude and will provide static, fixed ranges to be viewed from the 3000 feet altitude. The basic task of the test subjects will be to locate the target in the target area and report target detection as it occurs. The aircraft flight will be towards the center of the target area as shown on the briefing photographs. The briefing photographs are both vertical and oblique views of the terrain model with the target area marked on the vertical view.

   Prior to each run, you will have time for briefing using photographs of the terrain with the target area outlined. Your task during briefing will be to familiarize yourself with the target area.

   The targets used during this experiment are representative of targets 25 feet long and 12.5 feet high. The targets are two dimensional and inclined at a 45 degree angle to overcome the variations induced by shadows and to maintain a constant target presentation during the entire run. The shapes which are being used are shown below.



   The runs will be made from approximately 7 miles slant range to 2 miles, simulated.

Procedures

1. As soon as you arrive for the scheduled session, refer to the schedule posted in the briefing area and determine which target area applies for your first run.

2. Study the appropriate target area on the briefing photographs.

3. When it is your turn to take a run, you will be seated on the platform in the lab area. When the platform has been positioned for the run, you will be notified over the intercom and you should then locate the target area as marked on the briefing photograph.

4. As soon as you are ready to start the run, notify the experimenter via the intercom.

5. For the dynamic portion of the experiment, after the run has started, scan the target area in search of the target. Press the event mark button immediately upon detecting the target. The definition of target detection will be considered here to be that point when you feel that you have sufficient information concerning the suspected target such that you would, if flying, alter your flight path in order to better verify the existence of the target.

   The terrain model will be stopped when you signal target detection and you will be asked to describe the location of the detected target.

6. For the static test, the terrain model will be positioned at specific ranges. At each position you are to scan the target area in search of the target. You may take as much time as you like at each position. When you feel that you cannot detect a target after your search, inform the test monitor and the terrain model will be moved to the next closer position. When you have detected the target, inform the test monitor. You will then be asked to describe the location of the detected target.

7. At the conclusion of each run, return to the briefing room and prepare for your next run.

8. During the course of each session, please do not disclose to the other subjects any information relative to your findings or observations during a run. A comment may seem harmless relative to the experiment but it could help or hinder another subject and as a consequence, bias the results.

   Do not hesitate to ask questions of the experimenter concerning your individual performance or any procedures.

   Prior to the actual test runs, there will be familiarization runs to acquaint you with the experimental procedures.

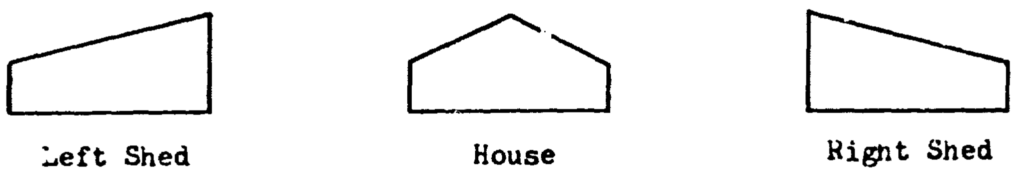
INSTRUCTIONS - TESTS 4 AND 5

DETERMINATION OF THE TARGET RECOGNITION THRESHOLDS OF THE UNAIDED EYE, DYNAMIC AND STATIC

1. The purpose of this experiment is to determine the target recognition capabilities of specially qualified subjects. The two tests will simulate the flight path of an attack aircraft flying towards a pre-briefed target position at 350 knots and 3000 feet altitude and will provide static fixed ranges to be viewed from the 3000 feet altitude. The basic task of the test subjects is to observe the target position as range closure occurs and report target recognition as soon as possible.

The target positions are marked on the vertical briefing photographs and will be briefed by the test monitor in the lab prior to each individual run. Both vertical and oblique view photographs of the terrain model will be available for briefing between each run. Your task during briefing will be to familiarize yourself with the target position.

The targets used during this experiment are representative of targets 25 feet long and 12.5 feet high. The targets are two dimensional and inclined at a 45 degree angle to overcome the variations induced by shadows and to maintain a constant target presentation during the entire run. The shapes which are being used are shown below.



The runs will be made from approximately 7 miles slant range to 2 miles, simulated.

Procedures

1. As soon as you arrive for the scheduled session, refer to the schedule posted in the briefing area and determine which target position applies for your first run.

2. Study the appropriate target position on the briefing photographs.

3. When it is your turn to make a run, you will be seated on the platform in the lab area. When the platform has been positioned for the run, you will be notified over the intercom and you should then locate the target position as marked on the briefing photograph. The test monitor will provide an additional target position briefing if necessary. You must be able to detect the target before the run can start.

4. As soon as you are ready to start the run, notify the monitor via the intercom.

5. For the dynamic portion of the experiment, you should press the event mark button immediately upon recognizing the target. Recognition is considered to occur when you have sufficient information concerning the target such that you would be willing in an operational situation, to commit yourself to weapon release at the earliest possible time while also being able to describe the target by name. Announce the name of the target to the monitor. The terrain model will be stopped when you signal target recognition.

6. For the static test, the terrain model will be positioned at specific ranges. At each range you will be asked to determine if you can identify the target. Take as much time as you like at each position. When you feel that you cannot recognize the target at its present range, notify the test monitor and the terrain model will be moved to the next closer position. When you recognize the target, announce the name of its shape to the test monitor.

7. At the conclusion of each run, return to the briefing room and prepare for your next run.

   During the course of each session, please do not disclose to the other subjects any information relative to your findings or observations during a run. A comment may seem harmless relative to the experiment but it could help or hinder another subject and as a consequence, bias the results.

   Do not hesitate to ask questions of the monitor concerning your individual performance or any precedures.

8. Prior to the actual test runs, there will be familiarization runs to acquaint you with the experimental procedures.

APPENDIX C

STATISTICAL ANALYSIS TABLES

I. To obtain basic statistical data, an analysis of variance was performed on each test. Summarized AOV tables are shown along with the F ratios and indications of significance. Extreme value substitutions were used for missing data.

Test 1 Dynamic Detection - Search

Source of Variation	df	Sums of Squares (SS)	F Ratio
Subjects (S)	4	6.53	3.12 *
Targets (T)	2	3.16	3.02 N.S.
Contrast (C)	5	27.44	10.49 **
S X T	8	4.28	1.02 N.S.
S X C	20	13.22	1.26 N.S.
T X C	10	55.16	10.54 **
Residual	40	20.92	
Total	89	130.73	

Note: * = Significance at .05 level
** = Significance at .01 level
N.S. = Not Significant

Test 1 Dynamic Recognition - Search

Source of Variation	df	Sums of Squares (SS)	F
S	4	18.38	13.81 **
T	2	3.70	5.56 **
C	5	62.43	37.50 **
S X T	8	4.94	1.85 N.S.
S X C	20	9.13	1.37 N.S.
T X C	10	33.52	10.07 **
Residual	40	13.31	
Total	89	145.43	

Test 2 Dynamic Detection - Briefed Targets

Source of Variation	df	Sums of Squares (SS)	F
S	4	7.06	24.37 **
T	2	1.03	7.14 **
C	3	5.22	24.04 **
S X T	8	0.47	0.81 N.S.
S X C	12	11.27	12.96 **
T X C	6	7.27	16.73 **
Residual	24	1.74	
		34.06	

Test 3 Static Detection - Briefed Targets

Source of Variation	df	Sums of Squares (SS)	F
[illegible]	4	5.54	35.9 **
[illegible]	2	0.64	8.35 **
[illegible]	3	3.39	29.32 **
S X T	8	0.35	1.12 N.S.
S X C	12	10.65	23.02 **
T X C	6	3.24	14.00 **
Residual	24	0.92	
Total	59	24.74	

Test 4 Dynamic Recognition - Briefed Targets

Source of Variation	df	Sums of Squares (SS)	F
S	4	15.49	9.28 **
T	2	2.38	2.28 N.S.
C	3	61.23	48.91 **
S X T	8	6.09	1.82 N.S.
S X C	12	2.01	0.40 N.S.
T X C	6	3.11	1.24 N.S.
Residual	24	10.02	
Total	59	100.32	

Test 5 Static Recognition - Briefed Targets

Source of Variation	df	Sums of Squares (SS)	F
S	4	14.85	17.14 **
T	2	0.73	1.68 N.S.
C	3	48.82	75.16 **
S X T	8	1.64	0.95 N.S.
S X C	12	7.79	3.00 *
T X C	6	3.26	2.51 *
Residual	24	5.20	2.51 *
Total	59	82.29	

II. Individual Test of Significance

At points where significance was indicated by the main effects, a t-test was performed when only two parameters were involved, e.g., at the 5 percent, 15 percent and 20 percent contrast levels.

At other points the Duncan Multiple Range Test was employed to test differences between values. The group means are shown in the following tables. The values which are underlined by the same line are not significantly different from each other. Those which are not connected to each other by the underline are significantly different at the .05 level of probability.

1. 10% Contrast Level

Group (test values)	4	3	1	6	2	4
Means	1.54	1.68	3.00	3.29	3.40	3.69

2. 25% Contrast Level

Group (test values)	4	3	6	5	1	2
Means	1.05	1.23	1.37	1.80	2.35	2.48

3. 35% Contrast Level

Group (test values)	4	3	6	5	1	2
Means	0.90	0.98	1.06	1.39	1.90	2.44

4. 50% Contrast Level

Group (test values)	2	1	4	3
Means	0.67	0.68	1.22	1.51

Tested Across Contrast Levels

5. Test 1 - Dynamic Detection - Search

Group (contrast levels)	20%	35%	15%	5%	25%	10%
Means	1.81	1.90	1.98	2.18	2.35	3.00

6. Test 1 - Dynamic Recognition - Search

Group (contrast levels)	20%	35%	25%	15%	10%	5%
Means	2.32	2.44	2.48	2.80	3.40	4.40

7. Test 2 - Dynamic Detection - Briefed

Group (contrast levels)	50%	35%	25%	10%
Means	0.68	0.98	1.23	1.68

8. Test 4 - Dynamic Recognition - Briefed

Group (contrast levels)	35%	50%	25%	10%
Means	1.39	1.51	1.80	3.69

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13. ABSTRACT

This study investigated the basic target acquisition capability of the unaided eye in a simulated real-world environment. Pilot performances on target detection and recognition tasks were examined under two test paradigms: 1 Search task for unbriefed targets and target areas; 2 Psychophysical threshold visual angle requirements for briefed targets. It was found that, as in previous studies using TV augmented viewing systems, there was a large decrement in performance at low contrast levels of 5% to 15% for both target detection and recognition. Differences in performance between search and threshold tests decreased to a constant value above approximately the 20% contrast level. At low target to background contrast levels, the general contrast level of background objects was higher than that of the target allowing maximum time for evaluation of all area objects. As a result, all high contrast non-targets were eliminated prior to reaching the visual threshold for the low contrast target which was then detected. Consequently, there were no significicent differences between search and threshold tasks at low contrast levels. Comparison of the static and dynamic threshold tests revealed no differences in the observer's performance with limited or unlimited time for target examination.

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